NORTH CAROLINA
DEPARTMENT OF CONSERVATION AND DEVELOPMENT

WILLIAM P. SAUNDERS, *Director*

DIVISION OF MINERAL RESOURCES
JASPER L. STUCKEY, *State Geologist*

BULLETIN NUMBER 71

EXPLANATORY TEXT FOR GEOLOGIC MAP OF NORTH CAROLINA

By

JASPER L. STUCKEY and STEPHEN G. CONRAD

RALEIGH

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LETTER OF TRANSMITTAL

Raleigh, North Carolina
February 4, 1958

To His Excellency, HONORABLE LUTHER H. HODGES
Governor of North Carolina

Sir:

I have the honor to submit herewith manuscript for publication as Bulletin No. 71, "Explanatory Text for Geologic Map of North Carolina". This text is an essential part of the new geologic map of North Carolina.

The new geologic map and this explanatory text contain a summary of the best information presently available on the geology of North Carolina. This information should be of real value to mining companies and individuals interested in the geology and mineral resources of the State.

Respectfully submitted,

WILLIAM P. SAUNDERS
Director

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EXPLANATORY TEXT FOR GEOLOGIC MAP OF NORTH CAROLINA

By

Jasper L. Stuckey and Stephen G. Conrad

ABSTRACT

A new geologic map of North Carolina, compiled from all available sources, is presented herewith. The accompanying text describes the rock units shown on the map.

The classification of rock units is based more on rock type than age relations. However, where possible formation names and age relations were used. The rocks were divided into the following four groups: Igneous and Metamorphic Rocks, Metavolcanic Rocks, Metasedimentary Rocks and Sedimentary Rocks.

Included in the Igneous and Metamorphic Rocks are gneisses and schists, granite gneisses, and granites and mafic igneous rocks. The gneisses and schists occur mostly in the upper Piedmont and Blue Ridge regions of the State and are presumably the oldest rocks present. With one exception, the granite gneisses are restricted to the Blue Ridge region and probably represent ancient igneous and sedimentary rocks that have been highly metamorphosed. The granites and mafic igneous rocks occur throughout the Piedmont and Blue Ridge regions, but are most abundant in the Piedmont. Included in this group are a wide variety of rock types that vary greatly in age, but all appear to be of igneous origin.

Metavolcanic Rocks occur in three distinct areas. The Carolina Slate belt occupies the largest area and is present in two separate but parallel belts. The main belt lies across the central part of the State in a northeast-southwest direction, and the second belt occurs along the western edge of the Coastal Plain. The Grandfather Mountain window is the second area of metavolcanic rocks, and it lies partly in the Blue Ridge and partly in the Piedmont Plateau in Avery, Watauga, Caldwell, Burke and McDowell Counties. Third is the Mount Rodgers volcanic group which occupies a relatively small area in the northwest corner of Ashe County. The Carolina Slate belt consists of volcanic-sedimentary formations, composed of slates, breccias, tuffs and flows. These rocks vary from acid, or rhyolitic, to basic, or andesitic, in composition and generally have a well developed cleavage. Rocks in the Grandfather Mountain window include schists, altered basalt and amygdaloidal basalt, metadiabase, and metarhyolite. The Mount Rodgers volcanic group is composed mostly of metarhyolite, including both tuffs and flows.

Rocks more or less metamorphosed but retaining enough of their original characteristics to indicate that they were sediments are classed as Metasedimentary Rocks. These rocks occur in four areas, commonly referred to as the Stokes County area, the Kings Mountain area, the Brevard area, and the Murphy area. The rocks in the Stokes County and Kings Mountain areas are much alike and are composed mostly of quartzite, schist, conglomerate and marble. These two areas are classed as the Stokes County and Kings Mountain belt. The other two areas are classed as the Brevard belt and the Murphy belt, and they are composed mostly of schists with lesser amounts of marble.

The oldest Sedimentary Rocks occur along the western edge of the State. These rocks belong to the Ocoee series and form much of the rugged topography in the Great Smoky Mountains. The Ocoee series is a very thick sequence of detrital rocks of graywacke type that rest unconformably on the older gneisses and granite gneisses. The Ocoee series is classed as Upper Precambrian in age. Overlying the Ocoee series is a sequence of somewhat better sorted detrital rocks called the Chilhowee group that are classed as Lower Cambrian in age. The Shady dolomite conformably overlies the Chilhowee group and is overlain by the Rome formation. Both of these formations are classed as Lower Cambrian.

Triassic sedimentary rocks occupy two belts in North Carolina. The Deep River belt, the largest, lies along the eastern edge of the Piedmont Plateau and extends from Anson County on the southwest to near Oxford, Granville County, on the northeast. The Dan River belt lies in the north central part of the Piedmont Plateau and extends from Davie and Yadkin Counties across Stokes and Rockingham

Counties into Virginia. The rocks of the two belts are very similar and consist of red, brown, purple and gray claystone, shale, sandstone, conglomerate and fanglomerate, and some coal.

The eastern one half of the State is underlain by sedimentary deposits that range from Upper Cretaceous to Recent in age. These sediments are commonly referred to as the Coastal Plain deposits and consist largely of unconsolidated sediments that include gravels, sands, clays, limestone and marls. The deposits of the Coastal Plain form a wedge-shaped block of sediments that increases in thickness from a feather edge along its western border to approximately 10,000 feet at Cape Hatteras. The sediments rest unconformably on crystalline rocks of Precambrian (?) age.

INTRODUCTION

A new geologic map of North Carolina, compiled from all available sources and supplemented by several months of fieldwork, is presented herewith. The accompanying text describes the rock units shown on the map and indicates briefly the importance of the units and their mineral deposits.

Prior to the preparation of the present map, the only geologic map of the State of North Carolina was one prepared by W. C. Kerr and published as a part of his Geology of North Carolina, Volume I, 1875. This map was revised slightly by J. A. Holmes in 1887 and published as a part of Ores of North Carolina by W. C. Kerr and G. B. Hanna (1893). Modifications of these maps, geologic maps of portions of the State found in various state reports, geologic folios and other reports of the U. S. Geological Survey, and a black and white map of North Carolina modified from the Geologic Map of the United States by the U. S. Geological Survey, 1932, served as a basis for interpreting the geology of North Carolina until the present map was compiled.

ACKNOWLEDGEMENTS

The geologic map of North Carolina presented herewith is a compilation from all available sources, published and unpublished. It is supplemented by several months of fieldwork, during which time areas of the State not previously covered were mapped on a reconnaissance basis, and other areas were checked for accuracy of mapping and to harmonize older maps. In addition to information obtained from older reports and from geologists who have had experience in the State in recent years, many others gave freely of their time and knowledge in making the present map possible. Thanks are gratefully expressed to all who aided in the project, and where possible, indebtedness for particular information is expressed below. An apology is hereby expressed to any who have been overlooked.

First, thanks should be given to Luther H. Hodges, Governor of North Carolina, who became interested in the project and made funds available for the necessary fieldwork and for compiling and publishing the map. Without his interest and enthusiastic support the map could not have been made available at the present time.

To Thomas B. Nolan, Director of the U. S. Geological Survey, and many members of the staff of that agency, thanks are gratefully extended. The U. S. Geological Survey cooperated informally by making available unpublished geologic maps of portions of the State, authorizing members of its staff to evaluate much of the material used, and furnishing the new base map on which the geology was compiled and published. Robert A. Laurence served as representative of the Survey in furnishing unpublished material and gave valuable assistance and advice on the map. Philip B. King reviewed the manuscript of the Piedmont and Mountain areas of the State and made many valuable suggestions. Jarvis B. Hadley edited the geology of the Great Smoky Mountains area and furnished valuable information on adjacent areas. W. C. Overstreet, A. A. Stromquist, and Phil Choquette contributed valuable data on the Central Piedmont region. H. M. Bannerman, C. A. Anderson, R. H. Lyddan, Harold Williams, J. P. Alders, and G. M. Fitzgerald furnished valuable information as to available maps and procedures to be used in the preparation of the map. The geology of the Coastal Plain is based on recent work of H. E. LeGrand and P. M. Brown. Robert L. Moravetz and his associates in the Office of Publications of the Survey gave valuable instructions on the preparation of the final manuscript and did photographic work that greatly reduced hand labor. The

Committee on Geologic Names checked the legend and approved the names and ages of many of the rock units and formations used on the map.

To make the map possible several areas in the State not previously mapped were mapped on a reconnaissance basis specifically for the project. R. J. Council and C. M. Llewellyn, Jr., mapped Alleghany, Wilkes, Surry, Yadkin, and parts of Ashe and Caldwell Counties. D. B. Sterrett aided Councill and Llewellyn and also mapped Alexander County. V. I. Mann and S. S. Alexander mapped Franklin, Warren, and parts of Vance, Henderson, Buncombe, and McDowell Counties and checked several areas in the western part of the State. W. A. White and E. C. Brett mapped Durham, Orange, and parts of Person and Granville Counties. R. L. Ingram and O. B. Eckhoff mapped Union, Stanly, and parts of Anson and Montgomery Counties. S. D. Heron, Jr., and W. D. Reves mapped Richmond and parts of Anson, Harnett, Lee, Moore, Montgomery, and Randolph Counties. J. M. Parker III and J. F. Conley mapped parts of Granville, Wake, Harnett, Moore, Lee, and Chatham Counties. J. L. Stuckey and S. G. Conrad mapped parts of Johnston, Wake, Harnett, Chatham, and Randolph Counties. S. D. Broadhurst checked several areas and made valuable contributinons to the project. T. L. Kesler, chief geologist of Foote Mineral Company, made available to the project the results of his mapping in the Kings Mountain district and offered valuable suggestions on other areas. In addition to field mapping, the men mentioned above, as well as E. Willard Berry, G. R. McCarthy, W. H. Wheeler, and E. L. Miller, Jr., gave valuable aid and criticism while the map was being compiled.

MAP UNITS

A geologic map is no better than the rock units or formations used. The map presented is not a final summary of the geology of North Carolina but a progress report in which an attempt has been made to present the best information available. To give meaning to the map units, more description is needed than can be presented in a conventional map explanation. To meet this need, the following descriptive text has been prepared to indicate the relative dependability of the map and point out areas where more work is most urgently needed. There are enough such areas to keep many geologists busy for a long time, and it is hoped that this map will serve as a stimulus and framework for increased geologic mapping in North Carolina.

Since the present map is based on fieldwork that is not sufficiently detailed to warrant a complete revision of nomenclature, an attempt has been made to show detail where detail exists and only generalized units where information is lacking. As a result, standardized units and names already in use and approved by the Committee on Geologic Names of the U. S. Geological Survey have been used wherever possible instead of introducing new ones.

Not all rock unit and formation names found in the literature are retained on the present map. In that portion of the Piedmont and Appalachian regions covered by various folios and unpublished maps of the U. S. Geological Survey are large areas which were mapped as Carolina gneiss and Roan gneiss. The formation names Carolina gneiss and Roan gneiss are no longer accepted by the U. S. Geological Survey and are not used on the present map. Many of the rocks classed as Carolina gneiss and Roan gneiss in older reports are shown as mica gneiss, mica schist, and hornblende gneiss on the present map.

The same procedure was followed in the Carolina Slate Belt of the Lower Piedmont. Prior to the preparation of the present map, two methods of classifying rock units in that belt had been employed. Laney (1910), Pogue (1910), and Stuckey (1928) mapped areas in the Carolina Slate Belt and classed the rocks as acid volcanic fragmental and flow materials, basic volcanic fragmental and flow materials, and bedded slate. Laney (1917) used the names Virgilina greenstone, Aaron slate, Hyco quartz porphyry, and Goshen schist for the volcanics in the Virgilina district. For the preparation of the present map it was not possible to do enough detailed fieldwork to apply these formation names to the whole slate belt; instead, the rock-unit names Felsic volcanics, Mafic volcanics and Bedded argillites (volcanic slate) were used, as these units are more easily recognized throughout the belt.

The Coastal Plain is doubtless the best mapped part of the State, and the formation names in common use there have been retained with few changes. In areas of the State, chiefly the Piedmont Plateau, where only limited mapping had been done previous to the preparation of the present map, rock units were set up and names most descriptive of these units were used.

DEPENDABILITY OF THE MAP

In the order of dependability the Coastal Plain is probably the best mapped part of the State. This is true with respect to the formations established and their age relations, but some of them vary in thickness from place to place, and it is not always easy to determine the exact limits of surface exposures. The region west of longitude 81° 30′ is the next best mapped part of the State, but here variations in metamorphism and complex structure make detail mapping difficult. East of longitude 81° 30′ and west of the western limits of the Coastal Plain less detailed work has been done, and the map is less complete. These three areas are discussed below in the order of dependability.

The first detailed map of the Coastal Plain was prepared by Clarke et al. (1912). In that report Stephenson considered the oldest Cretaceous rocks in North Carolina to be Lower Cretaceous and classed them as Patuxent in age. In the same report Miller considered the Trent formation to be Eocene and older than the Castle Hayne limestone. Cooke (1926) reclassified the Patuxent as the equivalent of the Tuscaloosa of Upper Cretaceous age, and Kellum (1926) placed the Trent formation in the Miocene. In subsequent years other changes were proposed by different geologists. Berry (1947) compiled a geologic map of the Coastal Plain from all available sources, which has served until the present time. LeGrand and Brown (1955) revised the geologic map of the Coastal Plain and combined the Trent formation with the Castle Hayne limestone. The present map contains all the formations in the Coastal Plain that are approved by the U. S. Geological Survey.

Considerable mapping has been done in the region west of longitude 81° 30′, but all the earlier work was highly generalized. Kerr (1875) divided the rocks of the region into three units, which he classed as Lower Laurentian, Upper Laurentian, and Huronian. The lower Laurentian corresponds to Paleozoic(?) granites of the present map; the Upper Laurentian corresponds to granite gneisses and gneisses and schists of the present map; and the Huronian corresponds to metavolcanics and sedimentary rocks older than Triassic of the present map. Holmes (1893 see Kerr and Hanna 1893) used essentially the same classification employed by Kerr but considered the three units to be Archean in age.

Pratt and Lewis (1905) classed the gneisses, schists, granites, diorite, and other crystalline rocks of the region as Precambrian in age and the conglomerates, quartzites, slates, etc., ac Ocoee of Cambrian age. They considered the peridotites, dunites, and related rocks as probably early Paleozoic in age.

During a period beginning in 1888 and ending about 1912, the U. S. Geological Survey mapped the region being considered, except Polk and parts of Henderson and Cleveland Counties, on 30-minute quadrangles. Nine of these were published as folios, and five were not published. The nine published folios are: Keith (1895, Knoxville f. 16; 1903, Cranberry f. 90; 1904, Asheville f. 116; 1905, Mount Mitchell f. 124; 1907a, Nantahala f. 143; 1907b, Pisgah f. 147; 1907c, Roan Mountain f. 151), LaForge and Phalen (1913, Ellijay f. 187), and Keith and Sterrett (1931, Gaffney-Kings Mountain f. 222). The five unpublished maps were: Keith (Cowee q. and Mt. Guyot q.); Keith and Sterrett (Morganton q. and Lincolnton q.); and Keith and Hayes (Murphy q.). The areal geologic map of the Cowee, Mt. Guyot, Morganton, and Murphy quadrangles were revised by Philip B. King and placed on open file by the U. S. Geological Survey and were available for use during the preparation of the present map.

In recent years, considerable mapping has been done in the region by the U. S. Geological Survey and the Tennessee Valley Authority, independently, and by the State of North Carolina in cooperation with these agencies. Philip B. King, Jarvis B. Hadley, and others of the U. S. Geological Survey mapped the Great Smoky Mountains and vicinity, and R. G. Yates, W. R. Griffitts, and W. C. Overstreet of the same agency mapped the Shelby quadrangle and adjacent areas. The U. S. Geological Survey in cooperation with the State of North Carolina carried out extensive mapping of mica mines in the area during World War II; and under the same program J. C. Olsen (1944) prepared a map of a part of the Spruce Pine district, E. N. Cameron (1951) prepared a map of a part of the Bryson City district, and J. M. Parker III (1952) prepared a map covering the geology and structure of a part of the Spruce Pine district. More recently, Kulp, Brobst et al. (unpublished) completed a geologic map of the Spruce Pine district covering some 250 square miles.

Geologists of the Tennessee Valley Authority, including Charles E. Hunter, Sam D. Broadhurst, and E. C. Van Horn, did extensive geological work

in the region prior to 1941. Under cooperation between the Tennessee Valley Authority and the State of North Carolina, E. C. Van Horn (1948) prepared a geologic map of the Murphy Marble Belt, and S. S. Oriel (1950) prepared a geologic map of the Hot Springs area. Under the same cooperative agreement a number of other reports on mineral resources were prepared, chief of which were by Hunter, et al. (1942), Murdock and Hunter (1946), Hunter and Hash (1949), Hash and Van Horn (1951), and Broadhurst and Hash (1953). All of these, and other reports not mentioned here, were freely drawn upon in compiling the map of the region west of longitude 81° 30′.

When compilation of the present map was begun, less detailed mapping had been done between longitude 81° 30′ and the western limits of the Coastal Plain than in any other part of the State. Laney (1910 and 1917), Pogue (1910), and Stuckey (1928) had prepared maps of a part of the Carolina Slate Belt. Stone (1912), Campbell (1923), and Reinemund (1955) had prepared maps of the Dan River and Deep River Coal Fields. Keith and Sterrett (1931) had mapped a part of Cleveland County, and Overstreet et al. (1953) had prepared a preliminary map of the Lincolnton quadrangle. J. M. Parker III, under a cooperative agreement between the U. S. Geological Survey and the State of North Carolina, had just completed a map, not yet published, of the Hamme Tungsten district covering parts of Granville and Vance Counties. These and a number of maps covering 50 to 100 square miles each, which had been prepared by graduate students in connection with theses problems, represented the only detailed mapping in the region.

Considerable mapping, however, had been done on a reconnaissance basis in connection with a cooperative project between the U. S. Geological Survey and the State of North Carolina for the study of ground water in the State. Mundorff (1946) prepared a geologic map of the Halifax area covering Nash, parts of Halifax, Northampton, and Wilson Counties in the Piedmont. Mundorff (1948) prepared a similar map of the Greensboro area covering Alamance, Caswell, Guilford, Rockingham, Forsyth, and Stokes Counties. LeGrand and Mundorff (1952) prepared the same sort of map of the Charlotte area covering Cabarrus, Mecklenburg, Gaston, Lincoln, Cleveland, Rutherford, and Polk Counties. LeGrand (1954) prepared a similar map of the Statesville area covering Alexander, Catawba, Iredell, Davie, Rowan, and Davidson Counties.

The maps listed plus the new mapping in the areas referred to under acknowledgments above served as the basis for compiling the present map of the State. Every possible precaution was taken to make the best possible use of the available data, but it should be pointed out that the map appears much more accurate than it actually is. No one is so well aware of its weak points and imperfections as the compilers are. A general precaution is issued to all users not to consider it a finished map, but a summation of the best information at present available on the geology of North Carolina.

STRUCTURE AND METAMORPHISM

In an area as complex in geology as that found in the Piedmont and Mountain regions of North Carolina, structural features and metamorphism of the rock units present many major problems. After giving much thought to the structural features of the rocks in the Piedmont and Mountain regions of the State and discussing the subject with many people who are more or less familiar with the region, it was decided that enough detailed information is not available to produce structure sections of real value. It was also decided that enough information is not available to warrant any detailed discussion of faulting, folding, metamorphism, unconformities, and facies changes. As a result, metamorphism is not discussed as such, and the only structural features shown on the map are a few faults of regional significance.

The U. S. Geological Survey is now engaged in the detailed mapping of a strip from the western edge of the Cumberland Plateau, across the Appalachian Mountains, the Piedmont Plateau, and the Coastal Plain. This strip is expected to cross a part of North Carolina. Perhaps, when it is completed, a revised map of North Carolina will be prepared which will contain more information on structure and metamorphism than is now available.

Structural features in the Coastal Plain are less complicated than in the Piedmont and Mountain regions. The formations generally strike northeast-southwest and dip gently a few feet per mile to the southeast. No faults or folds of any significance have been found in the region. A geologic cross-section across the Coastal Plain

with considerable subsurface data, obtained from deep-well records, is presented below.

DESCRIPTION OF ROCK UNITS

INTRODUCTION

In the explanation listed on the map and discussed below, a three-fold grouping of rock units has been used. First, the rock units have been grouped as sedimentary rocks, metasedimentary and metavolcanic rocks, and igneous and metamorphic rocks. Igneous and metamorphic rocks have been grouped together because some of the units used have characteristics of both igneous and metamorphic rocks. Second, an attempt has been made to group the rock units in the explanation according to their geographic distribution in the State. Third, as far as possible the sequence in the explanation represents the stratigraphic position of the rock units in the earth's crust. This is thought to be correct for the sedimentary rocks; however, in the case of metasedimentary rocks, metavolcanic rocks, and igneous and metamorphic rocks, the sequence in the explanation may not represent the true stratigraphic position. For example, the rock units used in the metavolcanic rocks of the Carolina Slate Belt are interbedded and, as a result, are not distinctly different in age. The exact ages of most of the granites listed as Paleozoic(?) and Paleozoic are not known, and as a result some may be the exact stratigraphic equivalents of others. The same holds true for the granite gneisses, as Eckelman and Kulp (1956) classed the Cranberry granite gneiss and the Henderson granite gneiss as stratigraphically equivalent. Finally, the exact ages of the gneisses and schists are not known, and it is quite probable that the units used contain materials differing greatly in ages.

IGNEOUS AND METAMORPHIC ROCKS

The gneisses, schists, and granite gneisses, listed as Precambrian(?), present a major problem in age classification. Many of these units in the Blue Ridge area, according to King (personal communication), are unconformable below Lower Cambrian and Upper Precambrian units and should be classed as Precambrian without the query. However, the difficulty comes in going southeast from the Blue Ridge area where similar units have no certain stratigraphic relations to the Cambrian or Upper Precambrian. The result is that Precambrian(?) looks incongruous in the Blue Ridge area where these rocks are in contact with Upper Precambrian and Lower Cambrian, but is well justified in the southeast. No simple solution could be found for the problem, and it has been left for map users to draw their own conclusions.

GNEISSES AND SCHISTS

PRECAMBRIAN(?)

The three units—Mica gneiss, Mica schist, and Hornblende gneiss—used in this grouping represent essentially Carolina gneiss and Roan gneiss in the areas mapped by Keith and similar materials outside these areas. The formation names Carolina gneiss and Roan gneiss are no longer accepted by the U. S. Geological Survey and are not used on the present map. The three units as presently constituted are too complex in composition to be given formation names, and it was thought best to use the rock-unit names, Mica gneiss, Mica schist, and Hornblende gneiss.

Mica Gneiss (mgn)

The Mica gneiss unit, as mapped, occurs over a wider area and probably underlies more square miles of the State than any other formation on the map. It is especially abundant in the Blue Ridge region and the western part of the Piedmont Plateau where it covers large areas. It is less abundant in the central part of the Piedmont Plateau but is common along the eastern part of that area. In the Blue Ridge and upper Piedmont areas, the Mica gneiss unit consists largely of Carolina gneiss as mapped by Keith (1903, 1904, 1905, 1907a, 1907b, 19007c, and 1931). In other parts of the State the Mica gneiss unit is in all respects comparable to that in the areas mapped by Keith.

The Mica gneiss unit consists of an immense series of mica gneiss, mica schist, and fine granitoid layers in which mica gneiss predominates. Most of these are light to dark gray in color, weathering to dull gray, greenish gray, or yellow. Varying amounts of garnet gneiss, garnet schist, kyanite gneiss, granite gneiss, hornblende gneiss, and crystalline limestone or marble are present in the unit at many localities. There are also included in the Mica gneiss unit younger bodies of

granite, diorite, and dikes and lenses of pegmatite too small or not well enough known to show on the map. Mica gneiss, which is the chief component of the Mica gneiss unit, is composed chiefly of quartz and feldspar with varying amounts of mica, both biotite and muscovite, with biotite predominating in many localities. Much of the Mica gneiss unit is doubtless metamorphosed sedimentary material, while some of it resembles granite gneiss and may well represent granite that has been strongly metamorphosed. Rock of this type has been quarried extensively around Asheville, Buncombe County; Hickory, Catawba County; Henderson, Vance County; and Raleigh, Wake County. This material was used in the construction of the present State Capitol in Raleigh, which was erected between 1830 and 1835.

Bands and lenses of mica schist, usually fine-grained and composed of quartz, muscovite, a little biotite, and very little feldspar are common in the Mica gneiss unit. Closely associated with the mica schist bands and lenses are extensive bands and zones of garnet gneiss, garnet schist, and kyanite gneiss. The garnet and kyanite gneisses and schists are too widespread to describe in detail here. Some of the better known garnet areas are near Marshall, Madison County; on Sugar Loaf Mountain near Willetts, the Savannah mine on the headwaters of Betty Creek, and the Presley mine near Speedwell in the upper Tuckaseegee valley, all in Jackson County; and on Shooting Creek, Clay County. An important belt of kyanite gneiss, six to eight miles wide, extends along the line of the Black and Great Craggy Mountains from Swannanoa, Buncombe County, to Bakersville, Mitchell County. The kyanite crystals vary in length from a fraction of an inch to three or four inches but average less than an inch. On weathered surfaces, they often stand out in relief, giving the rock a porphyritic appearance. Small garnets are often associated with the kyanite gneiss.

At many places throughout the Mica gneiss unit there are thin, interbedded layers of hornblende gneiss and schist, too small to show on the map. These are in all respects similar to the Hornblende gneiss unit described below.

Bodies of crystalline limestone or marble are present at many localities in the Mica gneiss unit. The more important of these occur near Marshall, Madison County; south of Bakersville, Mitchell County; eight miles northwest of Winston-Salem, Forsyth County; and near Germanton, Stokes County.

Included in the Mica gneiss unit at many places are dikes and lenses of pegmatite which are distinctly younger than the enclosing rock. These vary in thickness from a few inches to as much as 200 feet (Olson, 1946, p. 7) and are equally variable in length. Most of the kaolin and feldspar produced in North Carolina prior to 1945 came from pegmatite bodies. Throughout the history of mica mining in the State pegmatites have been, and still are, the chief source of sheet mica. A wide variety of commercially less important minerals are present in the dikes, and Olson (1944, p. 26) stated, "At least 44 different minerals have been reported from the Spruce Pine pegmatites." Spodumene-bearing pegmatites, which are the chief source of lithium in the United States, are abundant in the Mica gneiss unit south of Lincolnton in the Kings Mountain district.

The Mica gneiss is deeply weathered in most places and is covered with a thick layer of residual clay. As a result, fresh outcrops and ledges of solid rock are seldom seen except along streams, on steep slopes, and in the more mountainous areas. The residual clay contains fragments and layers of schist, quartz, mica, and gneiss. The cover of soil on the thick mantle of residual clay and weathered rock is usually light and thin.

Mica Schist (msh)

The Mica schist unit occurs most abundantly along the western border of the Piedmont Plateau, just east of the Blue Ridge Mountains, and extends intermittently completely across the State. In the vicinity of Kings Mountain and around Gastonia there are fairly large areas of mica schist, and smaller areas are widespread throughout the Piedmont Plateau. The main occurrences of this unit along the western border of the Piedmont Plateau, the area around Gastonia, and the areas throughout the lower Piedmont are essentially mica schist of the Carolina gneiss as mapped on the various folios of the U. S. Geological Survey.

North of the Yadkin River, the Mica schist unit consists principally of a thinly foliated muscovite-sericite schist. This unit also includes bands and zones of muscovite-biotite schist and some areas of mica gneiss, partly altered to mica schist. Injections of granite, too small to show on the map, are also common east of the Blue Ridge, and small amounts of hornblende gneiss and schist are present at many places in the unit. At many places, the Mica schist contains varying amounts of gar-

net, sillimanite, kyanite, magnetite, ilmenite, and pyrite.

South of the Yadkin River, the Mica schist unit consists basically of biotite schist. Three varieties of biotite schist are common, namely, biotite schist, biotite-muscovite schist, and sillimanite-biotite schist. All gradations exist among the three varieties. The sillimanite schist is in all places more contorted and sheared than the other varieties. A number of accessory minerals, including garnet, graphite, chlorite, and pyrite are present in the Mica schist unit. Pegmatites and narrow quartz veins occur throughout the mica schist. The pegmatites in general average less than a foot in thickness and rarely exceed four feet in length. Locally, they make up as much as one-half of the sillimanite-biotite schist. Overstreet and Griffitts (1955, pp. 551-556) gave an excellent description of the Mica schist unit and related rock units and discussed their mineral content in some detail.

Bands and zones of hornblende gneiss and hornblende schist, most of which are too small to show on the map, are common throughout the Mica schist unit. These hornblende rocks are generally of simple mineral composition and locally may contain varying amounts of garnet. Many bodies of foliated to massive granite, too small to show on the map, are present in the unit.

The Mica schist around Gastonia and in the other areas of the Piedmont Plateau to the east and northeast is essentially a fine-grained rock composed chiefly of quartz, muscovite and sericite mica. At places, the rock is a quartz-biotite schist, while at others it becomes a quartz-sericite, chlorite schist. The Mica schist evidently resulted from the metamorphism of sedimentary rocks that varied greatly in character from place to place. Weathering has been extensive, and outcrops of fresh rock are seldom seen except along streams and on steep slopes. The thick layer of residuum consists of clay mixed with fragments and layers of schist, quartz, and mica. The clay varies from yellow to dark red in color depending on the amount of biotite in the schist. The soil cover is usually light and thin.

Hornblende Gneiss (hgn)

The Hornblende gneiss unit is most abundant in the mountain region west of the Blue Ridge and north and northeast of Asheville. Several small areas occur west of the Blue Ridge in Clay and Macon Counties. In and parallel to the east side of the Blue Ridge small areas occur almost completely across the State. In the central part of the upper Piedmont, in the general vicinity of Hickory and Statesville, there are some relatively large areas. Smaller areas occur along the eastern edge of the Piedmont Plateau, particularly in Wake County.

The Hornblende gneiss unit consists essentially of Roan gneiss as mapped and defined by Keith (1903). The type locality of the Roan gneiss is Roan Mountain, which lies along the North Carolina-Tennessee line and extends southward into Mitchell County, North Carolina. Keith (1903) stated, "The Roan gneiss appears to cut the Carolina gneiss, but the contacts are so much metamorphosed that the fact cannot be proved." He considered the Roan gneiss as chiefly diorite and smaller amounts of gabbro, which had been intruded into older rocks and metamorphosed to hornblende gneiss and hornblende schist.

In recent years considerable attention has been given to Roan gneiss, as mapped and defined by Keith, and much of it is no longer considered to be of igneous origin. Kesler (1944, 1955) pointed out that bodies of hornblende gneiss in the Kings Mountain district (See Kings Mountain group below, p. 31) are metamorphosed, calcareous sediments. Parker (1952, p. 8) described the relation of the hornblende gneiss to the mica gneiss in the Spruce Pine district and concluded that certain thin, interbedded hornblende gneisses and actinolite-tremolite rocks may have been impure dolomitic limestones. He added: "The mafic mineralogic composition, however, coupled with the conformable relations to mica gneiss, has led most workers to believe that the ordinary hornblende rocks are metamorphosed mafic volcanic extrusives, and perhaps, in part at least, are conformable intrusive sills," and concluded, "Perhaps some of the hornblendic rocks are sedimentary in origin and some are igneous."

Brobst (unpublished) concluded that the Roan-type rocks (hornblende gneiss) are of sedimentary origin and stated, "The hornblende rocks, therefore, may represent the metamorphosed equivalent of impure carbonate layers in the sedimentary sequence." Overstreet and Griffitts (1955, p. 553) considered the hornblende gneiss between Kings Mountain and Marion, North Carolina, to be in part of igneous and in part of sedimentary origin.

The Hornblende gneiss unit consists essentially of hornblende gneiss and hornblende schist layers that vary from a fraction of an inch to many feet in thickness. The thin layers of hornblende gneiss and hornblende schist are interbedded with thin layers of mica gneiss and mica schist to the extent that portions of the Hornblende gneiss unit contains considerable mica gneiss and mica schist, and in the same way portions of the Mica gneiss unit and portions of the Mica schist unit contain considerable amounts of hornblende gneiss and hornblende schist.

The hornblendic rocks of the Hornblende gneiss unit include distinctly banded gneisses consisting of alternating layers of hornblende and feldspar, schistose rocks consisting almost entirely of coarse to fine hornblende needles, and nearly massive amphibolites that lack distinct foliation. The gneisses and schists are black to dark green and grade into one another by feldspar content. Quartz, feldspar, and hornblende are the chief minerals present, but varying amounts of biotite and chlorite are present at places.

Garnet is less abundant than in the Mica gneiss and Mica schist but at places becomes an important constituent of the Hornblende gneiss. Pegmatite dikes, some of which have furnished considerable amounts of feldspar and mica, are present at many places in the unit. Numerous bodies of soapstone and talcose schist are associated with the Hornblende gneiss unit especially in the Spruce Pine district. These bodies, which vary from five to 25 feet in thickness and consist of talc, soapstone, actinolite, biotite, chlorite, and vermiculite, appear to have been formed locally by secondary hydrothermal alteration of the hornblende gneiss.

In the more mountainous areas, the Hornblende gneiss often crops out as ledges and bold ridges, but at lower elevations it usually occupies broad, flat areas or lower ground. It weathers readily and is usually covered with a thick layer of residual clay mixed with rock fragments. This clay has a strong, dark-red color and is covered with a rich, fertile soil.

GRANITE GNEISSES

PRECAMBRIAN(?)

Along the western edge of the Piedmont Plateau and throughout much of the Blue Ridge Mountains area, according to Keith (see reference above), the older gneisses and schists have been intruded by a number of rocks which he classed as granites and granite gneisses (all highly metamorphosed) and named in various areas Cranberry granite, Henderson granite, Max Patch granite, and Beech granite. One unit, the Blowing Rock gneiss, he did not definitely class as a granite, even though he considered it intrusive into the older gneisses and the Cranberry granite.

Little has been published on these rocks since the work of Keith, but a number of workers in the area have made observations that caused them to doubt the validity of classing these units as either intrusive in origin or true granites in composition. This is true especially of the Cranberry and Henderson granites. Brobst (unpublished) listed and described the Cranberry granite as Cranberry gneiss. He discussed specifically some layers, typical of the Cranberry gneiss, which are interbedded with other metamorphic rocks along the northwest and east borders of the Bakersville-Plumtree area, Avery County, close to the contact of the large body of Cranberry gneiss that surrounds that part of the Spruce Pine district on three sides (Kulp and Brobst, 1956). Eckelman and Kulp (1956) considered the Cranberry and Henderson granites to be metasedimentary in origin and stratigraphically equivalent.

During the preparation of the present map it was not possible to restudy these units in detail. As a result, in the areas covered by published folios these units are shown as nearly as possible as originally mapped. Outside the areas covered by published folios, it is doubtful if the units correspond in all details to those in the areas covered by published maps. In view of the diversity of materials in the units and the intense metamorphism which has altered them, it was decided, after discussing the problem with a number of workers who have made observations in the field, to add the word gneiss to each unit originally classed as granite. As a result, each of these units originally classed as granite becomes a granite gneiss on the present map.

Unnamed Granite Gneiss (gru)

In Jackson, Haywood, and Swain Counties, west and north of Sylva, are areas of Unnamed granite gneiss. J. B. Hadley, on a map of the Great Smoky Mountains area furnished for use in the preparation of the present map, designated these rocks as granite gneiss without formation or unit names or

age designations. Hadley et al. (1955, p. 402) classed these rocks as Max Patch and Cranberry as mapped by Keith (1904) and described them as medium to very coarse genissic granites, generally gray but locally pink in color and containing minor amounts of leucogranite, amphibolite, pegmatite, and much blue quartz.

Cameron (1951, p. 10) described one of these areas near Bryson City in some detail. He classed the rocks of the area as granitic gneisses and described them as predominantly fine- to coarse-grained leucocratic and mesocratic gneisses, varying in composition from granitic to granodioritic with well developed foliation and lineation. He stated that the granite gneisses are cut by dikes of fine-grained granite and by dikes of medium-gray granite porphyry.

Granite Gneiss Complex (gnc)

Beginning a few miles northeast of Morganton and extending in a southwest direction across Burke, McDowell, Rutherford, and Polk Counties is an area underlain with rocks classed as Granite gneiss complex on the present map. About half of this area, in Burke and McDowell Counties, extending to latitude 35° 30′ N. and longitude 82° W. in Rutherford County, was mapped by Keith on the Morganton quadrangle, which was not published. He made field surveys in the Morganton quadrangle in the years 1896, 1899, 1900, 1901, and 1907 and was aided by D. B. Sterrett during the last year. Traverse sheets available in the U. S. Geological Survey files show complete coverage of the quadrangle. Based on these surveys, Philip B. King edited a geologic map of the Morganton quadrangle, which appears to be a generalization by Keith of a more detailed map not at present available.

The central part of the Morganton quadrangle, as edited by King, is underlain with a rock unit 5 to 15 miles wide which is classed as "Cranberry, Henderson (and other?) granites (Archean) (includes small areas of Roan gneiss)." Small areas of the same unit are shown in the southeast corner of the Morganton 30′ quadrangle and in the Shelby 15′ quadrangle. Rocks of this unit in Cleveland, Lincoln and Burke Counties were named Toluca quartz monzonite and classed as Ordovician in age by Griffitts and Overstreet (1952).

The main area of Granite gneiss complex extends southwest from the Morganton quadrangle across Rutherford County and well into Polk County. LeGrand and Mundorff (1952) mapped this unit in Rutherford County as mica schist and granite with schist predominant, and hornblende gneiss and granite interlain, and in Polk County as granite gneiss interlain with hornblende gneiss, and hornblende gneiss and granite interlain.

Attempts were made to harmonize the mapping done by LeGrand and Mundorff in Rutherford and Polk Counties with that done by Keith in the Morganton quadrangle. Attempts were also made to determine if the granitic material in the Granite gneiss complex as shown on the present map could be correlated with the granitic rocks in the southeast corner of the Morganton quadrangle and the northeast corner of the Shelby quadrangle, which Griffitts and Overstreet designated as Toluca quartz monzonite of Ordovician age.

The problem was not fully recognized until compilation of the map was well underway, and time was not available to work out all the details. Two field parties, working independently, spent several days in the area and decided that the materials mapped by LeGrand and Mundorff in Polk and Rutherford Counties and by Keith in the Morganton quadrangle are essentially the same. It was decided that in the time available no correlation could be made between the granites in the area and the Toluca quartz monzonite to the east and southeast.

The rock unit shown on the present map as Granite gneiss complex contains mica gneiss, mica schist, and hornblende gneiss similar to that in the gneisses and schists described above. In addition it contains granite gneiss similar to Henderson granite gneiss, and Cranberry granite gneiss and also younger granite.

Henderson Granite Gneiss (hgg)

The Henderson granite gneiss unit on the present map is essentially Henderson granite as originally named and described by Keith (1905) and further described (1907b). The Henderson granite as mapped by Keith is not shown in contact with Cranberry granite at any place on his maps. On the present map the main area of Henderson granite gneiss begins near Marion, McDowell County, and continues southwest to the South Carolina line. West of Marion, a narrow band continues northeast along the west side of the Shady dolomite and Erwin formation to the limits of the Mount Mitchell quadrangle. Recently, Eckelman and Kulp (1956) extended this band north-

east to near Linville Falls, McDowell County, where it makes contact with what they considered the southern extension of Cranberry granite as mapped by Keith in the Cranberry folio. They considered the Cranberry granite and the Henderson granite to be metasedimentary in origin and stratigraphically equivalent.

Keith (1905, p. 4) stated that the Henderson granite extended eastward into the Morganton quadrangle. A large area in the Morganton quadrangle (discussed above under Granite gneiss complex) was mapped as Cranberry, Henderson (and other?) granites No age relations are shown between Cranberry and Henderson granites on the Morganton quadrangle, but in the legend on the Mount Mitchell folio, Keith placed Henderson granite above Cranberry granite. The exact origin and age of the Henderson granite is unknown.

The Henderson granite gneiss, whatever its origin and age, is composed essentially of rocks with a pronounced gneissoid structure. Mineralogically, the rock consists of orthoclase, plagioclase, quartz, muscovite, and biotite, named in the order of their abundance. Biotite varies a great deal in amount but is usually subordinate. The gneiss is usually gray in color but becomes lighter on weathering. Porphyritic crystals of feldspar are a prominent feature of the gneiss, and at many places it is a typical augen gneiss. The porphyritic varieties are not limited to any particular areas or positions in the gneiss but are generally irregularly distributed through it. Porphyritic varieties of the gneiss grade into even-grained varieties, and the two varieties may be seen in a single exposure. Even-grained varieties of the gneiss are subordinate in amount to the porphyritic varieties.

The rocks of this unit have been greatly changed by metamorphism. In areas where the finer grained beds did not contain porphyritic crystals of feldspar, the rock has been metamorphosed into gneisses and schists similar to those of the Mica gneiss and Mica schist units. Areas of mica gneiss, mica schist, and hornblende gneiss, too small to show on the map, are included at many places in the Henderson granite gneiss.

Weathering of the Henderson granite gneiss varies greatly, and as a result the rock produces a varying landscape with strong cliffs and ridges in places and broad, flat areas in others. The Henderson granite gneiss has not been much used, but it offers an important source of dimension and crushed stone.

Cranberry Granite Gneiss (cgn)

The Cranberry granite gneiss unit on the present map consists essentially of Cranberry granite as originally named and described by Keith (1903), and further described (1904, 1905, and 1907c). The name Cranberry granite was first given to well developed exposures at Cranberry, Mitchell County, now Avery County. The relations of the Cranberry granite gneiss to the Henderson granite gneiss have been discussed above under Henderson granite gneiss.

Keith (references listed above) considered the Cranberry granite as igneous in origin, Archean in age, and intrusive into older formations. He described it as granite of varying texture and color, and schists and granitoid gneisses derived from granite. Included were small or local beds of schistose basalt, diorite, hornblende gneiss, and pegmatite.

As pointed out above, a number of workers in the area have made observations that caused them to doubt the validity of classifying the Cranberry granite as either intrusive in origin or a true granite in composition. Brobst (unpublished) described the unit as Cranberry gneiss, consisting of white to gray gneisses, composed chiefly of microcline, sodic plagioclase, and quartz, and stated that in some layers biotite, muscovite, and rarely hornblende may be present in amounts in excess of ten percent. He described the texture as cataclastic, with rounded and fractured porphyroblasts of microcline or plagioclase from three millimeters to one centimeter across the longest dimension.

The Cranberry granite gneiss unit occurs as strips and patches in the Mountain region along the northwest border of the State. These begin about the latitude of Asheville in Haywood and Madison Counties and continue northeast to the Virginia line. The strips and patches which make up the unit have an elongation which conforms in general with the northeast-southwest trend of the mountains.

The Cranberry granite gneiss, whatever its origin, is essentially a gneiss, which grades at places into schist. Logs of cores from 12 drill holes, varying in length from 400 to 1250 feet, which were drilled at the Cranberry iron mine in the type locality of the Cranberry granite in 1943-1944, were examined during the preparation of

this report. These logs, which were prepared by competent geologists, show the rock to be a typical gneiss. In addition to gneiss, narrow bands of hornblende gneiss, chlorite schist, and pegmatite were occasionally shown near the iron-ore veins. Some of the gneiss in the area is coarse-grained, but much of it is medium-grained and uniform in texture. In color, it varies from light to dark gray.

In general, the Cranberry granite gneiss is a medium-grained, even-textured rock that varies from light to dark gray in color. It is composed of quartz, orthoclase, plagioclase, muscovite, biotite, and occasionally hornblende. In some areas the rock is more or less porphyritic, and in some places it has a marked red appearance due to the presence of red feldspar. The gneiss contains many small areas of mica gneiss, mica schist, hornblende gneiss, schistose basalt, diorite, metadiabase, metarhyolite, and pegmatite.

The Cranberry granite gneiss has been used to a limited extent for chimneys, foundations, and bridge piers, but no major quarrying operations have developed. The rock withstands weathering quite well in natural exposures. It takes a good polish and should make an attractive building stone. Quarry sites for crushed stone are available at many places.

Perhaps the most important mineral deposits associated with the Cranberry granite gneiss are the magnetic iron ores near Cranberry, Avery County. The magnetite deposits, while surrounded by the Cranberry granite gneiss, did not originate with the gneiss. According to Bayley (1923) the iron ore was brought up by pegmatites and deposited in the gneiss. These iron-ore bodies have been of interest for more than a hundred years. Systematic mining was carried on intermittently between 1880 and 1928, and some 2,250,000 tons of crude ore, which produced some 1,500,000 tons of shipping ore containing 42 to 46 per cent iron, were mined.

Blowing Rock Gneiss (brgn)

The main area of Blowing Rock gneiss is a wedge-shaped body beginning a few miles north of Blowing Rock, Watauga County, extending southward almost completely across Caldwell County and coming to a point at its southern end. A small area is shown near Creston, Ashe County. Keith (1903) named the unit Blowing Rock gneiss because it is well developed near the town of Blowing Rock. He classed it as an igneous rock, intrusive into Cranberry granite and older formations and described it as chiefly dark, coarse, porphyritic gneiss.

The unit consists of two varieties, one containing large porphyritic crystals of orthoclase feldspar embedded in a groundmass of quartz, feldspar, biotite, and muscovite, and the other consisting of the same minerals in grains of uniform size. The porphyritic crystals vary in length from three inches down to one-quarter of an inch and are frequently twinned. Many layers of fine-grained, black and gray schist are present in the unit. Biotite is so abundant that both varieties of the rock have a rather dark-gray color. The unit as a whole has been so much altered by folding and metamorphism that while some of it is gneissoid, much of it is distinctly schistose.

The rocks weather slowly, and outcrops are abundant, as in the Blue Ridge near Blowing Rock and south of Boone. Complete weathering produces a reddish-yellow clay, which is usually covered with light, well drained, fertile soil.

The Blowing Rock gneiss has been used locally to a limited extent, but its importance as a building stone has not been realized. The formation contains material suitable for ornamental and building uses that can be obtained in great abundance.

Max Patch Granite Gneiss (mpgn)

Max Patch granite gneiss consists entirely of Max Patch granite as mapped by Keith (1904 and 1905). It was named for Max Patch Mountain in Madison County, North Carolina, which may be considered the type locality. In North Carolina the unit is limited to Haywood and Madison Counties, with small extensions in Cocke and Unicoi Counties, Tennessee. Keith classed the unit as almost wholly coarse grained, in places porphyritic and in places of uniform grain. It is composed of orthoclase, plagioclase, quartz, biotite, and a little muscovite. At many places crystals of orthoclase feldspar more than an inch long are present. The porphyritic variety is dull white to light gray in color, while the even-grained variety is darker in color due to the biotite present. Another variety of considerable extent is a coarse red granite which gets its color from the red feldspar present. The red feldspars are often partially altered to epidote, giving the rock an attractive color. In places the feldspar has been

so far replaced by epidote that this mineral composes one-third to one-half of the bulk of the rock.

The unit has been so completely metamorphosed that most of it has a gneissic to schistose structure, and little, if any, true granite remains unaltered. The porphyritic variety of the unit has been altered to augen gneiss, while the even-grained variety has been altered to gneiss or schist.

Weathering reduces the surface of the unit slowly, and as a result it commonly occupies higher elevations and steep slopes. Complete decay results in a reddish or brownish clay of no great depth. Where soils accumulate on gentle slopes, they are rich and fertile.

Mineral deposits are scarce in the Max Patch granite gneiss. A few small pegmatites near Lemon Gap, Madison County, contain small amounts of radioactive minerals. Some of the red feldspars, partly altered to epidote, make beautiful polished specimens, but the rocks of the unit have not become important as building materials.

Beech Granite Gneiss (bgn)

Beech granite gneiss consists of Beech granite as mapped by Keith (1903, 1905, and 1907c) and named for Beech Mountain, Avery County, where it is best developed. The largest area lies in and around Beech Mountain in Avery County, and extends westward into Carter County, Tennessee. Three other small areas are shown on the map, one around Blowing Rock in Watauga and Caldwell Counties, another west of Roan Mountain, Mitchell County, and extending into Carter County, Tennessee, and a third in the western part of Yancey County, extending into Unicoi County, Tennessee.

The unit consists of three varieties of granite gneiss. One is a coarse-grained, usually porphyritic rock, another is medium to fine grained, while the third is a coarse, red variety. In the porhyritic variety, crystals of orthoclase feldspar as much as two inches in length are often present. The chief minerals present in the unit are orthoclase and plagioclase feldspar, quartz, biotite, and a little muscovite. The porphyritic variety is dull white to light gray in color, the medium- to fine-grained variety is darker in color due to the presence of biotite mica, while the red variety gets its color from many pink or red feldspar crystals present.

The unit has been greatly changed by metamorphism. The mineral composition is essentially that of a granite, but the rocks composing the unit have a decided gneissic structure often becoming schistose with an increase of mica. The rocks of this unit are not too readily attacked by weathering and usually underlie higher ground. On complete weathering they produce a thin, brownish clay containing much sand. On gentle slopes where soils develop, they are strong and fertile.

Mineral deposits are not known to occur in the Beech granite gneiss. The unit contains rock varieties that should make excellent building and crushed stone, but due mainly to location, they have not been developed.

GRANITES AND MAFIC IGNEOUS ROCKS

Rocks of definite igneous origin that have undergone varying amounts of metamorphism and possess textures ranging from massive to gneissic are classed as Paleozoic(?), Paleozoic, and Triassic(?) on the present map. The units classed as Paleozoic(?) could probably be classed as Paleozoic without the query, as most of them, except the dunites, have been considered for years as late Carboniferous in age and were shown on the 1932 Geologic Map of the United States as Carboniferous(?). However, little has been done to prove or disprove this classification since 1932, and it was thought best to show them on the present map as Paleozoic(?).

PALEOZOIC(?)

There are five rock units in this group, four of which consist of granite, syenite, and diorite-gabbro. The fifth is classed as dunite and consists essentially of peridotite and pyroxenite, partly altered to talc, soapstone, and serpentine. The positions of these units in the column is arbitrary.

Dunite (du)

Dunite bodies are most abundant in the Blue Ridge Mountains where more than 250 outcrops occur in a northeast-southwest trending belt approximately 175 miles long. A few small bodies occur in the western half of the Piedmont Plateau, but the most important bodies outside the Blue Ridge Mountains are found in the northern part of Wake County. Only a few of the larger bodies in the Blue Ridge Mountains and those in Wake County are shown on the map. In the mountains

the bodies vary greatly in size. The smallest, near Otto, contains 1500 square feet, while the largest, near Swannanoa in Buncombe County, is four miles long with a maximum width of nearly one mile. One of the most interesting is a ring dike near Webster, Jackson County, with a major axis six miles long and a minor axis about four miles long. In Wake County the deposits vary in length from a few hundred feet to nearly two miles.

The age of the dunites is not definitely established. Keith (folios listed above) classed the dunites as Archean in age. He considered them intrusive into and closely related to the Roan gneiss but older than Cranberry and other granites which he classed as Archean in age. Pratt and Lewis (1905, p. 159) suggested that they may have been formed during the Taconic revolution at the end of the Ordovician period. Parker (1952), Brobst (unpublished) and King (1955) classed the dunites as Paleozoic in age.

The dunites consist chiefly of peridotite and pyroxenite, in part altered to talc, soapstone, and serpentine. Some deposits consist almost entirely of olivine, and some contain small amounts of pyroxene minerals, but most of them have been altered extensively by metamorphism and hydration. Many of the deposits in their present state consist of talc, soapstone, serpentine, asbestos, chlorite, vermiculite, and varying amounts of carbonate. Unlike most metamorphosed rocks they show only minor schistosity. Amphibole minerals, such as tremolite and actinolite, often form bunches and radiating clusters in soapstone.

The dunites in general weather slowly and often stand out as hills and ledges with much barren rock exposed at the surface. Final decay leaves a stiff yellow clay of little depth, and soils derived from this clay are of no value. Many of the deposits, particularly in the Blue Ridge Mountains, are covered sparsely with a stunted vegetation.

The dunites contain a wide variety of minerals that have been of interest at different times for many years. Many of the deposits contain varying amounts of chromite; and, while the production has been limited, much prospecting has been carried out for this mineral. At a few places, especially near Webster and Democrat, nickel silicate veins are conspicuous in the dunite, and considerable prospecting was carried out for nickel at Webster more than fifty years ago. The dunites contain varying amounts of corundum. Between 1871 and 1905, North Carolina was an important producer of corundum, most of which came from dunites. Talc and soapstone, associated with the dunites, have been of interest for many years, and small amounts have been produced. The most important period of activity was during World War II, when considerable amounts of ground talc and crayons were produced around Marshall, Madison County. In recent years, considerable interest has developed in the olivine associated with the dunites. Hunter (1941) described some twenty-five deposits in the Blue Ridge Mountains that contain 230 million tons of high-grade olivine and more than one billion tons of partly altered olivine. Varying amounts of vermiculite are associated with some of the dunites, and vermiculite production, which began in North Carolina in 1933, has continued intermittently since that time.

Granite (gr)

The rocks included in this unit are abundant along the western edge of the Coastal Plain and throughout the Piedmont Plateau. They were divided into three belts by Watson and Laney (1906), as follows: (1) Eastern Piedmont and Western Coastal Plain Belt; (2) Central Piedmont Belt (Carolina Igneous Belt); and (3) Western Piedmont Belt.

The rocks of the three belts are essentially granite according to the commonly accepted meaning of the term. They consist in general of quartz, orthoclase, plagioclase, biotite, a little muscovite, and varying amounts of accessory minerals, such as chlorite, epidote, titanite, zircon, and magnetite. On the basis of accessory minerals, varieties such as biotite granite and biotite-hornblende granite may be recognized. Councill (1954), on the basis of microscopic studies of the feldspars present, pointed out that in addition to granite, granodiorite is present, and quartz monzonite is common. He stated: "Many of the so-called granites of North Carolina approach more closely the mineral composition of granodiorite and/or quartz monzonite than normal granite."

Each of the three belts listed above contains distinctive granites that seem to justify a brief description.

The western boundary of the Eastern Piedmont and Western Coastal Plain Belt is formed by sedimentary rocks of Triassic age. In general the granites of this belt are massive, even-granular rocks, that show little effects of metamorphism. Jointing is common but not excessive at any place.

The textures present are chiefly medium to coarse grained. Porphyritic texture, though not abundant, is present at many localities, while fine-grained texture is seldom found. Two basic colors, one a light to medium gray and the other light to medium pink, sometimes approaching red, predominate. Outcrops, while not abundant, are common throughout the belt. Along stream valleys, outcrops form elongated masses and ledges; while in rolling topography, large boulders are often found. Away from streams in relatively flat topography, flat to dome-shaped masses often occur. Where it has not been removed by erosion, the granites are covered with a residuum varying from a few inches to as much as 25 to 40 feet thick. This residuum varies in color from buff, yellow, and red to reddish-brown, depending on the weathering of the underlying granite.

The granites of the Central Piedmont Belt (Carolina Igneous Belt) occupy a region several miles wide in the central part of the Piedmont Plateau. In this belt bodies of granite, varying greatly in shape and size, have intruded older rocks. On the basis of work by Mundorff (1948) and LeGrand and Mundorff (1952), the granites of this belt can be divided into three distinct geographic areas.

In one area, the granite, which Mundorff (1948) mapped as Sheared granite, crops out as an irregular and interrupted zone across northern Randolph County, southeastern Guilford County, most of Alamance County, the southeastern corner of Caswell County, and into central Person County. The granite is most commonly a coarse-grained rock of light-pink color, composed chiefly of orthoclase, plagioclase, quartz, and biotite. At a few places, it is light gray and medium grained, with plagioclase as the chief feldspar. The granite is badly crushed and broken with the development of a schistose or gneissic structure.

Basic dikes that vary from green to brown in color occur nearly everywhere in the granite in great numbers. Rarely does an outcrop of 200 to 300 feet of granite fail to expose one or more dikes, and at many places 10 to 12 dikes cut a granite body of that size. The dikes are more numerous and closely spaced along the margins of the granite. In some marginal exposures dike material is more abundant than granite. The dikes are fine grained, schistose in structure, and composed chiefly of chlorite, biotite, plagioclase, and augite. The granites of this area were intruded into basic volcanic rocks, largely of andesitic origin. Councill (1954, p. 56) described these granites as containing inclusions of basic volcanic rocks, probably of andesitic composition. It is probable that the dikes described above are in part dikes and in part inclusions from the basic volcanic rocks into which the granite was intruded.

In the second area, the granite, which Mundorff (1948) mapped as Porphyritic granite, crops out as irregularly shaped masses and elongated bodies in the southeastern corner of Rockingham County, across northwestern Guilford County, and in the southeastern half of Forsyth County. The granite in this area is coarse grained to porphyritic in texture and usually medium gray in color. Porphyritic crystals of orthoclase feldspar up to eight inches in length have been observed in this granite. The groundmass consists of feldspar, quartz, and biotite. At many places dikes and fingers of granite can be seen cutting the surrounding gneiss and schists parallel to the regional strike. The granites have intruded these rocks much more complexly than could be shown on the map. Except for gneissic structure around the margins of the bodies, which was probably inherited from the gneisses and schists into which the granite was intruded, no effects of shearing or metamorphism are present.

In the third area, the granite, which LeGrand and Mundorff (1952) and LeGrand (1954) mapped as Granite and Granite-diorite complex, begins about the Forsyth-Davidson county line, lies west of the Gold Hill fault, and continues southwest to the South Carolina line. Mundorff and LeGrand mapped the rocks of this area as Granite; Granite and diorite, granite predominant; and Diorite and granite, diorite predominant. On the present map, the first two of these have been combined in one unit, Granite. The diorite and granite, diorite predominant unit has been included in the Diorite-gabbro unit, which is discussed as a separate unit. In using this subdivision, the boundaries between the Granite unit and the Diorite-gabbro unit are necessarily somewhat indefinite. In this area granite occurs in some places as distinct bodies and in other places interlayered with diorite. Large bodies composed essentially of granite, occur in northern Davidson and eastern Davie Counties, in Rowan County, and in southern Iredell and Catawba Counties. Large areas of granite-diorite complex, in which granite predominates and which are shown as granite, occur in Davidson, Davie, Rowan, Cabarrus, Mecklenburg, and eastern Gaston and Lincoln Counties. In the

granite-diorite complex, the relations of the granite and diorite are uncertain. At many places, relations suggest that granite has intruded diorite, while at others it appears that diorite has intruded granite. In western Gaston and Lincoln Counties, granite has been intruded into gneisses and schists, forming a complex. Where granite predominates, this complex has been mapped as Granite. As a result, considerable gneiss and schist are included in the granites in Gaston and Lincoln Counties.

The granites of this area vary from fine grained, through medium grained to porphyritic in texture, with medium-grained and porphyritic texture predominating. Porphyritic granites are common along the western part of the area in Gaston, Iredell, Rowan, and Davie Counties and northwest of Concord, Cabarrus County. The other granites of the area vary from medium to fine-grained in texture, with medium-grained texture predominating. Outcrops are common and vary from large boulders to flat-surface areas. Colors vary from almost white through various shades of gray and pink to almost red. Minerals present consist of orthoclase, plagioclase, quartz, biotite, muscovite, and various accessory minerals. Where granite is associated with diorite, hornblende often occurs in the granite. Jointing is widespread but not excessive at any place in these rocks. The larger bodies, composed essentially of granite, show little metamorphism, but where granite has been intruded into gneisses and schists and in the granite diorite complexities, gneissic structure is often found. The rocks of this area react readily to the forces of weathering, and as a result the residuum varies in thickness from a few inches to many feet. The residuum covering the granites varies from buff through yellow to reddish-brown in color, while that covering the granite-diorite complex is much darker in color.

The granites of the Western Piedmont Belt consist of numerous bodies of varying size and shape lying between the Central Piedmont Belt and the Blue Ridge, exclusive of the Mount Airy granite in northern Surry County. The granite in northern Stokes and eastern Surry Counties are largely porphyritic. The others are medium to fine grained, with medium-grained rocks predominating. Most of these rocks may be classed as biotite granite, since biotite is common in all the outcrops. They are composed of orthoclase, plagioclase, quartz, biotite, a little muscovite, and minor accessory minerals. They vary from massive granite, showing no metamorphism, as in Stone Mountain, Wilkes County, to gneissic and schistose rock, where granites have been intruded into gneisses and schists. Outcrops are in the form of boulders and flat-surface exposures. Stone Mountain in northern Wilkes County, is a barren, granite monadnock, 500 to 600 feet high and measuring three to four miles in circumference at the base. The residuum in the various areas is similar in composition and color and equally as thick as that found in other granite regions of the State.

The rocks of the Granite unit as a whole have intruded a wide variety of older rocks. As a result, many small bodies and lenses of these older rocks, chiefly in the form of gneisses, schists, and metamorphosed volcanics, are included in the Granite unit. The rocks of this unit contain quartz veins, pegmatite dikes, and dikes of granite, quartz porphry, aplite, diorite, gabbro, and diabase, which vary in amounts and sizes from place to place.

Mineral deposits as such are not abundant in the Granite unit, but the granites of the unit are the basis of an important quarrying industry. Quarries too numerous to discuss here, but which have been described by Councill (1954), are widespread throughout the unit and furnish a large production of dimension and crushed granite.

Syenite (sy)

The only discrete body of syenite in the State is a ring dike, approximately 22 miles in circumference, located in the west-central part of Cabarrus County, LeGrand and Mundorff (1952). The outcrop of this syenite body varies in width from a few hundred feet at its southern limits to more than a mile along its western border, where it is crossed by Rocky River. The Syenite is more resistant to erosion than the surrounding rocks and stands out strongly in relief. The area of outcrop is generally marked by large boulders and pedistal rocks. The rock is an augite-syenite, composed largely of bluish-gray feldspar and augite. It is uniformly of coarse texture and massive in structure showing no effects of metamorphism. The absence of a fine-grained matrix permits the syenite to disintegrate into a residual granular material that makes excellent road metal.

Mount Airy Granite (mag)

The name, Mount Airy Granite, is introduced by the writers for a body of granite approximately eight miles long and four miles wide, which is

located around Mount Airy in northeastern Surry County. Much of the granite in this area is deeply weathered and covered with a thick layer of residumm. The most important outcrop is located one mile north of Mount Airy, where a body of fresh granite more than five thousand feet long occupies the crest of a prominent hill. The rock is a very light gray, nearly white, biotite granite of medium texture, composed of orthoclase, plagioclase, quartz, biotite, and minor amounts of apatite, zircon, muscovite, chlorite, and epidote. On the basis of the feldspar content, it is best classed as a quartz monzonite. The rock contains no injurious minerals and is free of joints and the effects of metamorphism. Quarrying was started at Mount Airy in 1890 and has continued uninterrupted since that time. Over the years, the quality and attractiveness of the rock has made Mount Airy granite a popular building stone. The absence of joints and lack of metamorphism have made possible the production of dimension stone of almost any desired size. The rock is used extensively for the construction of mausoleums, bridges, statues, and as architectural stone and curbing. Large amounts of crushed stone are produced also.

Diorite-Gabbro (digb)

Rock of the Diorite-gabbro unit are confined largely to the Central Piedmont Plateau, where they are associated with granites of the Central Piedmont Belt (the Carolina Igneous Belt), discussed above. They are most abundant west of the Gold Hill fault and south of Forsyth and Yadkin Counties, but a few small bodies are found in southeastern Guilford County, southern Caswell and Person Counties, and in the northeastern corners of Person and Granville Counties. The rocks of this unit range locally from diorite to gabbro but, as a whole, are intermediate between true diorite and gabbro. Some rocks consisting of diorite and granite, diorite predominating, are included in the unit. Areas of relatively true diorite and gabbro have been designated on the map, but most of the rock is shown as Diorite-gabbro. Bodies of almost normal diorite occur in southeastern Guilford, southern Caswell, and Person Counties. Bodies of nearly normal gabbro are found in northeastern Granville and Person Counties, inside the syenite ring dike in Cabarrus County, and from a short distance north of Barber south to Bear Poplar in Rowan County. The Diorite-gabbro is a coarse-textured rock that is distinctly massive and not closely jointed. It is composed chiefly of hornblende or pyroxene, plagioclase, and varying amounts of quartz and accessory minerals. In some places it is exposed as rounded boulders or flat outcrops that are not much weathered, but in most places it is deeply weathered, and covered with a thick layer of soil that is deep red or brown and relatively fertile. At several places, both on interstream areas and along valleys, shallow depressions resembling sinks in limestone are present. These appear to be the result of weathering and solution of the Diorite-gabbro.

PALEOZOIC

The four units in this group have been studied and described by Olson (1944), Griffitts and Overstreet (1952), Parker (1952), and Overstreet and Griffitts (1955) and classed as Paleozoic. These workers did not agree completely as to the position the units occupy in the Paleozoic, but they were in agreement in classing them as Paleozoic in age. Two of these, Toluca quartz monzonite and Cherryville quartz monzonite, consist in part of Whiteside granite as mapped by Keith and Sterrett (1931).

Toluca Quartz Monzonite (tqm)

Toluca quartz monzonite consists of numerous bodies of varying shape and size, occupying a belt extending across central and western Cleveland County, western Lincoln County, and into southern Burke County. It was named by Griffitts and Overstreet (1952) for the town of Toluca in the western edge of Lincoln County. Individual bodies vary from a few inches to several thousand feet thick and from a few feet to ten miles long. In general, these are parallel to the foliation of the mica gneiss into which they were intruded but occasionally cross it. Outcrops are not abundant as the rock is deeply weathered and underlies broad areas of light-gray soil. Toluca quartz monzonite is typically a medium gray, moderately gneissic rock. Usually, the smaller bodies are more strongly foliated than the larger, which, while gneissic throughout, are more strongly foliated near the margins. Chief minerals are oligoclase, microcline, orthoclase, quartz, and biotite. Minor amounts of garnet and muscovite and small amounts of apatite, zircon, ilmenite, and monazite are present. The rock is characterized by a wide variation in texture and composition. The texture

is everywhere gneissic, but the size, shape, and arrangement of the grains vary widely.

Monazite-bearing pegmatites genetically associated with the quartz monzonite inject it and occur parallel to the foliation of the surrounding gneiss. These dikes vary from a few inches to several feet in thickness and often attain lengths of several hundred feet. Overstreet and Griffitts (1955, p. 556) classed the Toluca quartz monzonite as early Ordovician in age.

Cherryville Quartz Monzonite (cqm)

Cherryville quartz monzonite occupies a broad belt across eastern Cleveland, western Gaston, and central Lincoln Counties. The unit was named by Griffitts and Overstreet (1952) for Cherryville, Gaston County. Outcrops are not abundant as the rock underlies thick layers of light-gray soil. South of Cherryville, the belt is parallel to the structure of the older rocks, but north of Cherryville, it bends eastward and crosses the structures of the older rocks. The Cherryville quartz monzonite contains many inclusions of country rock. It is essentially a gray, even-grained, massive to slightly gneissic rock, consisting chiefly of two varieties, one containing muscovite and biotite and the other containing muscovite but no biotite. It is, in general, a medium-grained rock, composed of oligoclase, microcline, quartz, muscovite, and biotite, with minor amounts of zircon, ilmenite, and apatite. Overstreet and Griffitts (1955, p. 556) classed the Cherryville quartz monzonite as probably Devonian in age.

Two major varieties of pegmatite dikes, spodumene-bearing and mica-bearing, are related to the Cherryville quartz monzonite. Spodumene-bearing pegmatites are restricted to the tin-spodumene belt that lies along the east side of the Cherryville quartz monzonite bodies. These dikes are most commonly in gneiss, but some extend into the quartz monzonite bodies. These dikes vary from zoned and nongneissic, north of Kings Mountain, to gneissic and nonzoned, south of Kings Mountain. Mica-bearing pegmatites that are well zoned occur in the northern part of the Lincolnton and Shelby quadrangles. These form dikes that cross the foliation of the enclosing gneiss and also the Toluca quarts monzonite.

Whiteside Granite (wg)

The Whiteside granite unit on the present map is essentially Whiteside granite as originally named and described by Keith (1907b). It was named for the cliffs of Whiteside Mountain, Jackson County, where it is well developed. On the present map, it is shown as several areas of varying sizes and shapes, along the southern boundary of the State in Henderson, Transylvania, and Macon Counties. The granite is a light-gray, even-grained, massive rock, composed of orthoclase, plagioclase, quartz, muscovite, biotite, and minor amounts of magnetite, ilmenite, and garnet. Biotite varies in amount and is often absent. The granite was injected into older rocks, parallel to their foliation, and often contains inclusions of gneiss and schist. Two varieties were described by Keith. One is fine to medium grained and massive, the other contains a decided flow banding. Outcrops vary with topography, and much of the granite is covered with thick layers of light red to yellowish soil mixed with sand.

Alaskite (al)

The Alaskite unit consists essentially of a coarse-grained pegmatitic granite that crops out near Spruce Pine, Mitchell County, as a number of bodies varying greatly in size and shape. The rock, which has been of interest to miners in the Spruce Pine district for several years, was designated by Hunter (1940) as alaskite. It consists essentially of oligoclase, quartz, microcline, and muscovite, listed in the order of abundance. Dark-colored minerals are almost absent, but small amounts of biotite and garnet occur at places near inclusions or contacts with country rock and are apparently products of contamination. The rock is not true alaskite, but the name is so well established in the Spruce Pine district that it is used here. The alaskite masses are granitoid in texture and uniform in grain size and mineral content. Much of the rock is sufficiently coarse-grained to be called pegmatite, but its uniformity and wide extent make the name Alaskite appropriate. The alaskite bodies contain many inclusions of gneiss and schist near their margins, but internally they are relatively free of such. Alaskite bodies containing inclusions of gneiss and schist often grade into gneiss and schist, containing numerous bands and lenses of alaskite. Most inclusions, as well as alaskite bands and lenses, are parallel to one another and to the foliation of the country rock.

Pegmatites occur in all parts of the alaskite, but the average size and number is greater near the margins of the alaskite bodies. The pegmatites

in alaskite and in the surrounding gneisses and schists are important sources of mica, feldspar, kaolin, and other minerals, for the production of which the Spruce Pine district is widely recognized. Sheet mica is obtained almost exclusively from pegmatites. For many years, feldspar and kaolin were produced from fresh and weathered pegmatites. As the demands for these minerals increased, attention was directed to alaskite, and it is now the chief source of feldspar, kaolin, and flake, or scrap, mica. Large bodies of unaltered alaskite serve as a source of feldspar by flotation. In many places, the alaskite is deeply weathered, often to depths approximating a hundred feet. Many of these weathered deposits are rich in kaolin and contains considerable flake mica. Most of the kaolin and a large part of the flake mica produced in the State are being obtained from weathered alaskite. Economically, Alaskite is one of the most important rock units shown on the present map.

TRIASSIC(?)

Two units, Bakersville gabbro and Diabase dikes, are shown as Triassic(?) on the present map. Diabase dikes have been considered of possible Triassic age for many years and probably should be classed as Triassic without the query; however, there is some question as to the exact age of the Bakersville gabbro. Keith (1903) first named this unit and described it in the text as Juratrias(?) but showed it in the legend on the geologic map as Juratrias without the query. The unit has received considerable attention in recent years, but its exact age is still in doubt. Kulp and Brobst (unpublished) showed Bakersville gabbro on an unpublished geologic map of the Spruce Pine district as Devonian. Brobst (1955, pp. 584-585) described the unit briefly and pointed out that it is considered younger than the alaskite and pegmatites. As to age, he stated, "The Bakersville might have been emplaced between the late Ordovician or early Silurian and the Triassic." The Committee on Geologic Names of the U. S. Geological Survey recommends Triassic(?) for the Bakersville gabbro, and it is so shown on the present map.

Bakersville Gabbro (TRg)

Bakersville gabbro outcrops are shown on the map near Bakersville, Mitchell County, and south and west of Elk Park and Cranberry, Avery County. The major outcrop near Bakersville is roughly triangular in shape, with a maximum length of five miles and a maximum width near the base of the triangle of about three miles. The outcrop near Elk Park and Cranberry is about two miles long and one mile wide. A number of outcrops too small to be shown on the map are found in the general area. Keith (1903) named the unit for Bakersville, Mitchell County, and described it briefly. It is a dense, hard, unmetamorphosed rock, nearly black when fresh but becoming reddish brown on weathering. It is composed chiefly of plagioclase, hornblende, and pyroxene in crystals of medium size, with small amounts of magnetite, epidote, and garnet as accessory minerals. The texture is usually massive and granular but occasionally becomes aplitic. Outcrops consist of spheroidal masses and boulders mixed in a dark-brown clay.

Diabase Dikes (TRd)

Diabase dikes of probable Triassic are widely distributed throughout the Piedmont and Mountain regions of North Carolina. They are most abundant in and adjacent to sedimentary rocks of Triassic age along the eastern and central Piedmont region, but become less common in the western Piedmont and are found sparingly in the Blue Ridge region. They also occur frequently along the western edge of the Coastal Plain where pre-Triassic rocks are not covered by younger sediments. Because of the wide distribution and limited area of outcrop, Diabase dikes are shown in only two localities on the map. One of these is the Deep River basin in Chatham, Lee, and Moore Counties, and the other is an unusually long dike northeast of Morganton, Burke County. In the Deep River basin, according to Reinemund (1955), who gave an excellent description of the diabase intrusives in that basin, dikes, sills, and sill-like masses occupy about four percent of the Triassic rocks. Diabase dikes in the Deep River basin vary in width from less than an inch to 320 feet and in length from a few feet to nearly seven miles. Most dikes in the area are between 20 and 75 feet wide and are fairly constant in width for several thousand feet of length. Sills and sill-like intrusives of diabase are abundant in the Deep River basin Triassic sediments and range in thickness up to 400 feet. In the Morganton area, an unusual diabase dike extends in a northwest-southeast direction with minor interruptions for nearly twenty miles.

The diabase intrusives are massive, crystalline, unmetamorphosed rock that varies in color from dark gray, grayish black to nearly black. The minerals and textures present are those commonly found in normal diabase, except some of the larger sills which more nearly approach gabbro in composition. In general, the dikes form low ridges and divides, but in the Deep River basin, they are an important influence on drainage patterns. The direction of flow of several streams in the area is determined in part by the trends of the dikes. Many springs occur along these dikes, and it has been learned from experience that water-well sites located near dikes are more likely to furnish good yields. Outcrops are common in the form of boulders, which were produced by spheroidal weathering along the joints in the rock. Two types of soil, one a brown or grayish-brown, silty loam and the other a dark red to brownish-red heavy clay loam, occur over areas of diabase. Both soil types are underlain with yellow to dark red, sticky clays.

METAVOLCANIC ROCKS

Metavolcanic rocks occur in three distinct geographic areas in North Carolina. First and most important is the Carolina Slate Belt which actually consists of two belts, one lying across the central part of the State, and the other lying along the eastern edge of the Piedmont Plateau and western edge of the Coastal Plain. Second is the Grandfather Mountain Window, which lies partly in the Blue Ridge area and partly in the Piedmont Plateau in Avery, Watauga, Caldwell, Burke, and McDowell Counties. Third is a relatively small area known as the Mount Rogers volcanic group which lies in the northwestern corner of Ashe County.

PRECAMBRIAN OR LOWER PALEOZOIC(?)

CAROLINA SLATE BELT

Rocks of the Carolina Slate Belt, because of their complex character and well defined cleavage, have been called slates. Actually, they consist of volcanic-sedimentary formations, composed of slates, breccias, tuffs, and flows. The flows are interbedded with the breccias and tuffs, while the tuffs pass gradationally into slates. These rocks vary from acid or rhyolitic to basic or andesitic in composition and generally have a well developed cleavage, which gives them a slaty appearance.

Rocks of the Carolina Slate Belt series actually form two belts in the State. The first and most important of these, and the one which Olmstead (1825) first called the Great Slate Formation, crosses the central part of the State in a northeast direction from Anson and Union Counties on the south to Granville and Person Counties on the north. This belt varies in width from 25 to 60 miles and consists of metavolcanic rocks intruded at many places by younger granites, described above. The second belt, in which metavolcanic rocks are exposed as irregular bodies of varying size and shape, lies along the eastern edge of the Piedmont Plateau and western edge of the Coastal Plain. This belt, in which Kerr (1875, p. 131) first recognized rocks similar to those of the Great Slate Formation of Olmstead, begins in Richmond County on the south, varies greatly in width, and continues in a northeast direction to Northampton County on the north.

Olmstead (1825), Emmons (1856), and Kerr (1875) considered the rocks of the slate belt as sedimentary in origin but described them as slates, containing beds of porphyry, hone or whetstone slate, breccia, and conglomerate. Emmons (1856) placed the rocks in the Taconic System, while Kerr (1875) classed them as Huronian in age, which, according to his geologic column, is a division of the Archean. Williams (1894) recognized for the first time the presence of volcanic rocks in the slates. He described exposures of volcanic flows, breccias, and tuffs, which had been sheared into slates by dynamic metamorphism. Nitze and Hanna (1896) recognized volcanic rocks in the slate belt and considered the Bedded argillites (volcanic slate) of the present map as younger than the volcanics and called them Monroe slates. It is now recognized that the Monroe slates represent a better bedded, less metamorphosed portion of the slate-belt rocks.

Following the work of Williams (1894), reports by Laney (1910 and 1917), Pogue (1910), and Stuckey (1928) emphasized the importance of volcanic rocks in the slate belt but did not overlook entirely the presence of sedimentary material. These authors considered the rocks of the slate belt to be largely of volcanic derivation but recognized the presence of considerable sedimentary (nonvolcanic) material and classed the whole series as laid down by sedimentary processes.

Mapping carried out for the compilation of the present map tended to verify the above findings. Rocks which may be classed as flows, breccias,

tuffs, and shales or slates were found to be present. All of these, except flows, contain considerable amounts of nonvolcanic materials. The flows, breccias, tuffs, and slates are all interbedded and do not occupy any definite stratigraphic positions in the series. The flows vary from rhyolite, through andesite, to basalt. The rhyolites and andesites vary from fine grained to coarsely porphyritic, while the basalts are often amygdaloidal. The breccias vary from rhyolitic to andesitic in composition and in size from an inch to nearly a foot in diameter. The fragments of the breccias are, in turn, fragmental, apparently of a pyroclastic origin. Some of the fragments in the breccias are sharply angular, while many are rounded, indicating transportation and deposition. The tuffs are generally of acid composition and composed of fragments less than an inch in diameter. These fragments, which vary from angular to rounded, are embedded in much fine-grained material apparently of nonvolcanic origin. Beginning at Siler City, Chatham County, and continuing southwest for 15 to 20 miles are several beds of quartz conglomerate, varying in width from a few inches to 250 feet and of unknown length. The quartz pebbles are less than an inch in diameter and well rounded, further indicating sedimentary processes. The shales or slates, which are generally well bedded, are composed of fine-grained volcanic material and much land waste. Finally, much of the finer material in the breccias, tuffs, and portions of the shales or slates strongly resembles metasiltstone and metagraywacke of some of the metagraywacke rocks in other areas, further indicating sedimentary origin.

In view of the above facts, there is a strong trend on the part of some workers to drop the term metavolcanic and use one that defines the rock more nearly as sediments. That idea was considered for the present map but was discarded in favor of metavolcanics, since the rocks of the slate belt are largely of volcanic origin, and the terminology has been in the literature for more than sixty years.

No fossils have been discovered in the slate belt, and the age of the rocks is not known. For many years they were classed as Precambrian, while in recent years there has been a trend towards classing them as lower Paleozoic. On the present map, they are classed as Precambrian or Lower Paleozoic(?). They have been divided into three units, Felsic volcanics, Mafic volcanics, and Bedded argillites (volcanic slate).

Felsic Volcanics (fvs)

Rocks of the Felsic volcanics unit occupy about half of the Carolina Slate Belt in the central part of the State and are the only rocks shown in that portion of the belt lying along the eastern part of the Piedmont Plateau and western part of the Coastal Plain. In the central part of the State, rocks of the Felsic volcanics unit occupy much of the eastern part of the Carolina Slate Belt northeast of Anson, Richmond, and Stanly Counties.

The rocks of the Felsic volcanics unit are composed largely of materials of volcanic flow or fragmental origin. The flows are essentially rhyolite, while the fragmental materials vary from rhyolitic to dacitic in composition. The fragmental rocks consist of breccia and coarse and fine tuff, with coarse and fine tuff making up the greater portion of the unit. Lenses of bedded slate and mafic volcanics, too small to show on the map, are present in this unit.

The rhyolite occurs as narrow bands and lenses interbedded with the breccia and tuff. It is dense and indistinctly porphyritic with a dark gray to bluish color, and, on fresh surfaces, shows a greasy luster. Flow lines are often present and are best seen on weathered surfaces, while amygdaloidal structure is also present. In porphyritic specimens the minerals are plagioclase, orthoclase, and quartz. None of the rhyolite outcrops show any effects of metamorphism.

The fragmental rocks consist of breccia and coarse and fine tuff. The coarse tuff predominates and contains the breccia and fine tuff as interbedded bands and lenses. The fragments composing these rocks are angular to well rounded and vary in size from nearly a foot to a fraction of an inch in diameter. The larger fragments are internally fragmental, while the finer material grades into Bedded argillites (volcanic slate). At places, within a few inches, fine fragmental rock grades into a rock showing bedding planes. When freshly broken, the rock proves to be made up of quartz and feldspar grains and rock fragments, some of which show a flow structure, set in a dense bluish or greenish groundmass. In general, the rocks of this unit have a light gray to greenish color.

In the central part of the State, the rocks of the Felsic volcanics unit vary from massive to schistose. At places, the fragmental texture of the rock may be seen, but much of the rock has been strongly metamorphosed and possesses a well defined slaty cleavage that strikes northeast-

southwest and dips to the northwest in the southern part of the area and to the southeast in the northern part. The felsic volcanics weather to a light gray soil usually underlain by yellow to light-red clay. The layer of soil and clay is usually thick, and outcrops of fresh rock are not abundant.

Along the eastern part of the Piedmont Plateau and western edge of the Coastal Plain, all the metavolcanics of the Carolina Slate Belt are shown as the Felsic volcanics unit on the present map. The rocks are deeply weathered and covered by a thick layer of soil. As a result, outcrops of fresh rock are scarce, and mapping is difficult. Mundorff (1946) showed these rocks on the legend of his map as Slates, schists, and metamorphosed volcanics. He considered the series as metamorphosed sedimentary and igneous rocks, including lavas, tuffs, and breccias. He did not mention rhyolite or rocks of a mafic character but did refer to a coarse breccia near Roanoke Rapids. In the course of fieldwork for the present map no rhyolite was seen, but small amounts of breccia and in one or two places small outcrops of mafic volcanics too small to show on the present map, were observed.

In general, the rocks of this area consist of coarse to fine tuff and bedded slate, with which bodies of gneiss and schist are present in many places. The tuffs and bedded slates are present throughout the area in about equal amounts. In some places, bedded slate predominates, and in others tuffs predominate. These rocks are usually altered near igneous intrusions to garnetiferous mica schist, mica hornblende schist, or biotite schist. Some bodies of gneiss and schist not apparently related to igneous intrusives are present and probably represent metamorphosed nonvolcanic sediments. Six miles west of Smithfield, Johnston County, on the east side of U. S. Highway 70, is a large outcrop that resembles quartzite and contains kyanite crystals. It may be siliceous sediment metamorphosed to quartzite, or it may be a silicified tuff. Similar outcrops, except for the kyanite, are found north of Princeton in the eastern part of Johnston County. The bedded slates are dark blue to greenish gray when fresh and become various shades of yellow and red when weathered, while the tuffs, gneisses, and schists are generally gray, yellow, or brown. All these rocks have been moderately metamorphosed and contain a cleavage that strikes northeast and stands nearly vertical.

Mafic Volcanics (mvs)

Rocks of the Mafic volcanics unit are shown on the present map only in the northern two-thirds of Carolina Slate Belt in the central part of the State. They are scattered throughout the area but are more abundant along the western side. The rocks of this unit consist largely of flows and fragmental materials of volcanic origin. The flows vary from andesite to basalt, while the fragmentals are generally andesitic in composition. Lenses of bedded slate and felsic volcanics, too small to show on the map, are present in this unit.

The andesite and basalt occur as narrow bands and lenses interbedded with the fragmentals. The andesite is dark green in color, usually massive or fine grained, but occasionally coarsely porphyritic. A coarse porphyritic variety, with hornblende crystals up to two inches long, occurs in western Randolph County. The basalt is dark to nearly black and often amygdaloidal. Both the andesite and basalt are characterized by the lack of a well defined cleavage. Minerals present consist of epidote, plagioclase, quartz, secondary calcite, and iron oxides. Epidote is the most abundant mineral present, giving the rock its green color.

The fragmentals consist of breccias and tuffs of andesitic composition, often intermixed with much fine-grained material. In places these rocks are fine grained and lack the fragmental appearance. In such areas, one of which may be seen along U. S. Highway 64 for a mile west of Haw River, the rock strongly resembles a graywacke. The breccias and tuffs contain much epidote and often have a greenish color. Other colors vary from dark gray to nearly black. In addition to epidote, plagioclase, and quartz, secondary calcite and iron oxides are present. The mafic fragmentals are not as strongly metamorphosed as the felsic fragmentals but contain a cleavage that strikes northeast and dips to the northwest in the southern part of the area and to the southeast in the northern part. These rocks are usually covered with a thick layer of dark-red residuum.

Bedded Argillites (Volcanic Slate) (ar)

Bedded argillites (volcanic slate), commonly referred to as slate, bedded slate, or volcanic slate, occur in the southern part of the Carolina Slate Belt in the central part of the State and extend north as far as the central part of Davidson and Randolph Counties. A few small areas are shown on the east side of the belt in Montgomery, Moore,

and Chatham Counties. There are also some small areas east of the Jonesboro fault in Anson and Richmond Counties.

The unit as shown on the map is chiefly bedded argillites or bedded slate, but many lenses of felsic and mafic volcanics, too small to show on the map, are included. The Bedded argillites (volcanic slate) consist chiefly of dark-colored or bluish shales or slates, which are usually massive and thick bedded. However, the beds occasionally show very finely marked bedding planes. Contacts between the slates and the tuffs are usually gradational, and often a single hand specimen will show gradation from a bedded slate to a fine-grained tuff. Much of the slate is massive and jointed, showing little effects of metamorphism, while in other places it has been strongly metamorphosed and shows a well defined, slaty cleavage. The cleavage, or schistosity, does not in most places correspond to the bedding planes of the rock. In places, especially near igneous intrusive and mineralized zones, the slate is highly silicified and often resembles a chert. The slates are deeply weathered, and good outcrops of fresh rock are seldom seen. In general, they are covered with a thick layer of residuum, which consists of light soil on top and yellowish, decomposed slate beneath.

The rocks of the Carolina Slate Belt have furnished mineral resources of considerable importance for many years. Between 1800 and 1860, the slate belt produced important amounts of gold. Gold mining is no longer important, but many quartz veins in the area contain varying amounts of silver, lead, zinc, and copper. The production of these metals has never been large, but the veins continue to attract the attention of individuals and mining companies. Important deposits of pyrophyllite occur in Moore, Randolph, Alamance, Orange, and Granville Counties, from which large amounts of pyrophyllite are being mined. The Bedded argillites (volcanic slate) are deeply weathered in many places to clay and shale, suitable for the manufacture of clay products. Brick and tile are being produced in large amounts from these materials. Lightweight aggregate is being produced in Stanly County from semiweathered slate. Rocks of the Carolina Slate Belt were first used for building purposes at Hillsboro in colonial days. More recently, both felsic and mafic volcanics were quarried near Hillsboro and used in the construction of the buildings on the West Campus of Duke University. Bedded slate is being quarried in southern Davidson County and southern Montgomery County and used as building stone and flagstone. When fresh and unweathered, the bedded slate makes an excellent crushed stone, and large amounts are being produced.

Upper Precambrian

Grandfather Mountain Window

The Grandfather Mountain window area is nearly surrounded by the Grandfather Mountain fault and lies partly in the Blue Ridge and partly in the Piedmont Plateau in Avery, Watauga, Caldwell, Burke, and McDowell Counties. Keith (1903) mapped and described four units in that area, as follows: Linville metadiabase, Montezuma schist, Flattop schist, and Metarhyolite. His names and descriptions have been retained on the present map.

Linville Metadiabase (lmd)

Linville metadiabase occurs as irregular outcrops associated with Montezuma schist, Flattop schist, Cambrian quartzite, and as narrow bands in Cranberry granite gneiss. It occurs as flows, which came up through cracks in older rocks, such as those now filled with metadiabase in the Cranberry granite. The metadiabase contains plagioclase, largely altered to epidote, chlorite, and quartz. Other original minerals, olivine and augite, are largely replaced by hornblende, epidote, and chlorite. Epidote sometimes occurs as grains and masses as much as six inches in diameter. The rock has been much metamorphosed, but at places its original character is retained. It is generally of a dull-yellowish color, due to epidote, chlorite, and hornblende. The metadiabase weathers readily and usually is covered by a thick layer of dark-red and brown clay.

Montezuma Schist (mtsh)

The Montezuma schist consists of fine-grained epidotic and chloritic schists and amygdaloidal beds and is rather uniform in appearance. Originally it was probably a basalt, but it has been so completely metamorphosed that only a few traces of flow banding remain. Amygdaloidal beds are the commonest evidence of its original nature. The color of the rock when fresh is bluish black, gray, or green, becoming more green and yellowish green on weathering. The chief min-

erals are chlorite and feldspar in abundance and muscovite, epidote, and quartz in small amounts. The schists weather slowly and usually form high ledges and cliffs, while the amygdaloidal beds weather more readily and are covered with thick clay of yellow or red color.

Flattop Schist (fsh)

This unit, named for Flattop Mountain, Watauga County, consists of black, dark-blue, bluish-green, and greenish-gray schists, which weather to a yellow or greenish-gray color. The schist is commonly banded. The bands, which are seldom more than half an inch thick, consist of quartz and feldspar grains of varying size, and the rock strongly resembles a sandy slate of sedimentary origin. Where not banded, the schist contains pyrophyritic crystals of feldspar and amygdules, indicating that it is volcanic in origin. Originally, the rock was probably a lava flow, but it has been strongly metamorphosed, and most of the original minerals have been replaced by secondary quartz, feldspar, and mica. The Flattop schist resists decay and forms ridges and mountains. Final decay produces a reddish, sandy clay.

Metarhyolite (mry)

This unit consists mainly of fine metarhyolite but occasionally contains layers which show porphyritic crystals of feldspar and quartz. When fresh, the rock is dark blue, dark gray, and bluish black; but, when weathered, it becomes dull yellow and yellowish gray. It occurs as intrusive sheets and dikes in older rocks and as surface flows. The unit has been greatly metamorphosed, but flow banding and amygdules are occasionally poorly preserved. The rocks of this unit vary from rhyolite, little altered, to a well defined schist, depending on the original nature of the rocks and the amount of metamorphism. These rocks weather slowly, but final decay produces a thin layer of fine yellow and red clay.

MOUNT ROGERS VOLCANIC GROUP (mr)

The Mount Rogers volcanic group, named by Stose and Stose (1944, pp. 410-411) for Mount Rogers, the highest point in Virginia, underlies a small area in the northwest corner of Ashe County, North Carolina, adjacent to Tennessee and Virginia. Jonas and Stose (1939, pp. 590-591) and Rogers (1953, p. 23) have summarized very well the characteristics of the group. The unit consists of purplish and greenish metavolcanic rocks, chiefy metarhyolite, but apparently contains tuffs as well as flows. The rock has been strongly metamorphosed and possesses a slaty cleavage. Some of it is good slate; but, despite the foliation, much of the rock forms massive ledges and blocks. The foliation of the more massive rock is interrupted by small, irregular masses of quartz, while the slaty rock commonly contains small, very thin lenses of chlorite and epidote. Interbedded with the volcanic rocks are layers of conglomerate, graywacke, and nonvolcanic silty shale or slate. The rocks of the group often crop out in large masses, and at places in Tennessee and Virginia, they form high, rough mountains. They weather to a thin, very strong, light soil.

METASEDIMENTARY ROCKS

Rocks more or less metamorphosed but retaining enough of their original characteristics to indicate that they were originally sediments are classed as metasedimentary rocks on the present map. They occur in four areas, commonly known as the Kings Mountain area, the Stokes County area, the Brevard area, and the Murphy area. The rocks in the Stokes County area and the Kings Mountain area appear to be much alike and stratigraphically equivalent. On the present map, these two areas are classed as the Stokes County and Kings Mountain Belt, while the other two are classed as the Brevard Belt and the Murphy Belt. The ages of the rocks in these three belts are not definitely known, but it is assumed that their position in the explanation is essentially correct.

UPPER PRECAMBRIAN(?) OR LOWER PALEOZOIC(?)

STOKES COUNTY AND KINGS MOUNTAIN BELT

Kings Mountain Group (kmg)

The rocks of this unit fall into two natural groups, one of which consists of highly siliceous rock, while the other consists largely of calcareous rock. The siliceous group consists in the Kings Mountain part of the belt, of slate, rhyolite, volcanics, quartzite, and conglomerate, and, in the Stokes County part of the belt, of mica schist, quartz mica schist, and quartzite. In the Kings Mountain area, the slates and phyllites are essentially sericitic schist. Pyroclastic textures are not abundant but are common enough to indicate that

volcanics make up an important part of the group. Quartzite and conglomerate are present in beds that crop out prominently at many places. In the Stokes County area, the chief rocks are quartzite, mica schist, and quartz mica schist, apparently interbedded. At a few places in the Stokes County area is found a flexible sandstone, consisting of fine, interlocking quartz grains and mica flakes. Throughout the Stokes County and Kings Mountain Belt, the siliceous rocks form the higher elevations and prominent ridges, often called mountains.

The calcareous group is confined largely to the Kings Mountain part of the belt and consists of crystalline limestone, dolomite, and calcareous metashales. In the southern part of Catawba County and the northern part of Lincoln County, interesting amounts of hornblende gneiss are found, apparently interbedded with quartzite, that probably represent metamorphosed calcareous shales. One important body of crystalline limestone occurs near Siloam, Yadkin County, in the Stokes County part of the belt. Other limestone bodies, mentioned above, occur in mica gneiss along the southern border of the belt in Yadkin and Stokes Counties, that may or may not belong in this group.

The limestone and dolomite of the belt have been quarried intermittently for years, and a large quarry is in operation near Kings Mountain. The quartzite in the Kings Mountain part of the belt contains interesting amounts of kyanite, but it has not been mined in North Carolina.

Lower Cambrian(?)

Brevard Belt

Brevard Schist (bv)

The Brevard Belt begins in North Carolina at the state line, southwest of Brevard, for which it was named by Keith (1907b), crosses Transylvania, Henderson, and Buncombe Counties, and ends in McDowell County, a short distance northwest of Old Fort. The Brevard schist, the only unit in this belt, consists mainly of schist and slate. Schist, which predominates, is of a dark-bluish-black, bluish-black, black, or dark-gray color. Lenses of limestone, varying from a few hundred feet to more than a mile in length and up to 250 feet in thickness, are scattered widely throughout the belt. Thin layers of quartzite and conglomerate are occasionally found. Graphite is widely disseminated as small flakes through large masses of the rock and occasionally forms lenses that are graphite schist. The schists are composed of quartz and muscovite, through which are scattered numerous small grains of iron oxides, while garnets are occasionally found. The slates are essentially clay slates. The rocks are all essentially fine grained except for occasional layers of quartzite and conglomerate.

Some years ago graphite was produced from the northern part of the belt, west of Old Fort but none has been mined in recent years. Considerable amounts of crystalline limestone have been produced for lime, agricultural lime, and aggregate near Fletcher, Henderson County. At the present time, crushed stone for aggregate is the chief material being produced. Near Etowah, Henderson County, a clay slate weathered to a shale is being used for the manufacture of brick.

Murphy Belt

Rocks of the Murphy belt occur in the southwest corner of the State, where Keith (1907a) mapped a synclinal structure and named the following formations: Tusquitee quartzite, Brasstown schist, Valleytown formation, Murphy marble, Andrews schist, and Nottely quartzite. The Tusquitee quartzite and Nottely quartzite could not be shown on the present map due to the limited area each covers. They are much alike and consist essentially of white quartzite. On the present map the Brasstown schist and Valleytown formation are shown as separate units, while the Murphy marble and Andrews schist are combined as one unit due to the limited area each covers.

Brasstown Schist (bt)

The Brasstown schist consists of schists and slates more or less banded. The greater part of the formation consists of banded ottrelite schist, but some of it is banded slate with little or no ottrelite. All the rocks are dark colored and vary from dark blue or bluish black to dark gray. They are usually marked by a fine banding of light and dark-gray colors. The light layers are often siliceous and sometimes grade through sandy slate into sandstone. The slates are argillaceous, while the schists are more siliceous. The most outstanding mineral is ottrelite of dull-bluish or greenish-gray color, but varying amounts of garnet and staurolite are present at many places. The rocks

weather to thin, yellow and brown clay soils of poor fertility.

Valleytown Formation (vt)

The rocks of the Valleytown formation vary widely from place to place but consist mainly of mica schist and fine-banded gneiss. However, in many areas, mica slate, argillaceous slate, graywacke, feldspathic sandstone, and occasionally beds of coarse quartzite are present. These rocks are usually dark colored, varying from dark gray to grayish black. In most of the rocks the minerals that can be identified in hand specimens are quartz and mica in the mica schist and feldspar and quartz in the feldspathic sandstone; however, bands of ottrelite schist and garnet schist are often present. The rocks of this unit are resistant to weathering and stand up as knobs and ridges. Final decay produces a thin soil, full of rock fragments, which is of little value.

Andrews schist—Murphy Marble (ma)

Because of limited areal extent, the Murphy marble and Andrews schist have been combined into one unit on the present map. The Murphy marble is found in two areas, one along the Nantahala and Valley Rivers in Swain and Cherokee Counties, and the other along Peachtree and Little Brasstown Creeks in Cherokee County. The rock consists entirely of marble, rather fine grained but completely crystalline. The predominant color is white, but a large part of the marble is dark gray or blue, and many layers consists of banded or mottled blue and white. In the Red Marble Gap some of the layers have a rose-pink color. Van Horn (1948 pp. 12-13) established a zoning or stratigraphic sequence in the marble, based on color and secondary minerals. The Murphy marble passes by gradation into the Andrews schist and often contains bands of schist. Other than crystals of calcite and dolomite, the marble contains mica, quartz, garnet, and ottrelite along gradational zones and talc and tremolite at many places. Much of the marble underlies low ground and is covered with stream deposits of sand and gravel.

The Andrews schist consists essentially of thin beds of calcareous schist of relatively light-gray color. It is characterized by a large number of ottrelite cyrstals, which lie at right angles to the bedding. Muscovite and biotite occur frequently, lie parallel to the bedding, and are the chief cause of the schistose planes in the rock. The Andrews schist weathers readily and usually underlies low ground. It is usually covered wit ha residual, micaceous clay, that grades downward into fresh rock.

The Murphy marble is an attractive rock, and over the years considerable dimension and crushed stone have been produced from it. Building, monumental, and crushed stone are being produced near Marble, Cherokee County, and crushed aggregate and agricultural limestone are being produced near Hewitts, Swain County. A white, fine-grained dolomite, occupying the approximate center of the marble, often contains deposits of high-grade talc. This talc has been mined for years and is presently being produced about one mile southwest of Murphy. Iron ore in the form of limonite occurs at many places, usually associated with the Andrews schist. Production was carried on for many years with maximum development and mining taking place between 1917 and 1920. No production has been made since 1921.

SEDIMENTARY ROCKS

Upper Precambrian

OCOEE SERIES

Along the western boundary of the State, in Cherokee, Graham, Swain, Haywood, and Madison Counties and smaller areas in Clay, Jackson, and Mitchell Counties, occurs a thick sequence of clastic, nonfossiliferous sedimentary rocks. These rocks were named the Ocoee conglomerate and slates by Safford (1856) from the exposures along the Ocoee River between Parksville and Ducktown, Tennessee. Keith (1895, 1896, 1904, and 1907c) mapped and named a number of formations within the series; however, his formations differed considerably from one folio to another. Rodgers (1953), in his compilation of a geologic map of East Tennessee, dealt very thoroughly with the Ocoee series and went to some length to present the problems and interpretations associated with the Ocoee series. Detailed work recently completed by King (1949, 1955), Hadley et al. (1955), and others in the Great Smoky Mountains greatly changed Keith's original work and has rendered his interpretation and correlation of the series obsolete. The clasification used on the present map represents the results, both published and unpublished, of this detail mapping by the U. S. Geological Survey, with simplification to adjust

it to the cartographic units and scale used on this map.

The age of the Ocoee series has been debated since it was first recognized and named by Safford over one hundred years ago. It has been classed by various workers all the way from Lower Silurian, to Precambrian, to age unknown. However, it is now considered established that the series underlies, perhaps in part disconformably (King, 1949, Rodgers, 1956), the Lower Cambrian Chilhowee group, and rests with profound unconformity on highly metamorphosed Precambrian gneisses and granite gneisses (Hadley et al., 1955). In a forthcoming paper by P. B. King and others of the Great Smoky Mountain field group, they recommend that the Ocoee series be designated Upper Precambrian. In keeping with their latest work, which will undoubtedly be accepted by the Committee on Geologic Names of the U. S. Geological Survey, the Ocoee series is here classed as Upper Precambrian.

From Madison County southwestward the Ocoee series forms a wedge of sedimentary rocks which attains a thickness of at least 25,000 feet in the Great Smoky Mountains (King, 1955). It consists entirely of clastic sediments except for rare, thin beds of limestone. Great quantities of material derived from preexisting plutonic rocks, including much blue quartz like that found in the Max Patch and Cranberry granite gneisses, are contained in the series.

The rocks which compose the lower part of the series are in part of the graywacke facies and include slate, phyllite, sandstone, graywacke, and conglomerate. Textures range from fine- and medium-grained sandstone to fine-grained conglomerate. The graywackes contain many grains of quartz and feldspar, but the matrix is argillaceous material that has been altered to sericite and chlorite. Graded bedding is a striking feature of the graywackes. Quartz-feldspar conglomerates with pebbles one-fourth to one-half inch in size are common.

The upper part of the series is a very thick and uniform body of finer grained rocks, composed mostly of siltstone, shale, and slate but also includes lentils of coarse conglomerate, sandstone, and limestone.

According to Hadley et al. (1955): "The distribution of rocks in the Great Smoky Mountains is controlled largely by two great low-angle faults, the Great Smoky fault and the Greenbrier fault, which divide the country into areas of broadly contrasting landscapes. The Great Smoky fault emerges along the southeast side of the Tennessee Valley, separating it from a belt of foothills, beginning with Chilhowee Mountain proper. The Greenbrier fault marks, throughout much of its course, the boundary between the foothill area and the higher mountains of the Great Smokies . . ."

The Great Smoky fault, and faults related to it, extends from Virginia across Tennessee into Georgia. Rocks of early Paleozoic and Precambrian age have been thrust northwestward more than ten miles (Hadley et al., 1955) over younger Paleozoic rocks of the Tennessee Valley. The Great Smoky fault does not enter North Carolina anywhere along its course but is mentioned here because of its importance to the Ocoee series.

A considerable part of the Greenbrier fault also lies in Tennessee, but parts of it are present in Haywood, Swain, and Jackson Counties, North Carolina. Throughout most of its course it brings rocks of the Great Smoky conglomerate over those of the Snowbird formation. However, in the southeast part of the mountain belt in Swain County, the fault can be traced through the underlying Snowbird into the basement rocks. The age of the Greenbrier fault has been stated by Hadley et al. (1955) to be younger than the earliest deformation of the rocks of the Ocoee series, but older than the folding and thrusting in the region as well as the thermal peak of post-Ocoee regional metamorphism.

Faulted and folded rocks of the Ocoee series along with Precambrian granite gneisses and rocks of the Lower Cambrian series are involved in one of the most complicated and unusual structural units found in the southern Appalachians. The structure is known as the Hot Springs window, and it occupies a small area that lies in the western part of Madison County along the North Carolina-Tennessee boundary. Keith (1904) first mapped the area, but Stose and Stose (1944, 1947) were the first to recognize the presence of a window in the Hot Springs area. Oriel (1950) mapped the area in detail, and his interpretation of the geology and structure was followed on the present map. The results of his study show that the Hot Springs window is framed by four thrust faults, with the possibility that another thrust fault is present within the window. The thrust faults dip forty to fifty degrees in most localities, and the movement of the thrust sheets was relatively to the northwest.

Most of the rocks of the Ocoee series show

effects of regional metamorphism; however, the degree of metamorphism varies considerably. In the northwest part of the foothills area in Tennessee, the degree of metamorphism is very low, even slaty cleavage is lacking in some places, but it increases in intensity to the southeast. Slaty cleavage gradually becomes dominant in the finer grained rocks in the southeast part of the foothill area, where mineral assemblages characteristic of the muscovite-chlorite subfacies are widespread (Hadley et al., 1955). Continuing southeastward into the mountain area and North Carolina, the slates pass into phyllites, and the phyllites, into fine-grained schists with conspicuous porphyroblasts. Sandstones and conglomerates grade from rocks in which the quartz grains and pebbles are generally flattened to those which are conspicuously foliated.

The rocks of the Ocoee series in North Carolina belong mostly to the middle-grade metamorphic zone, as indicated by the presence of biotite, almandine garnet, kyanite, and staurolite. These minerals occur in rock types such as biotite-quartz schist, kyanite and staurolite-bearing schists, and garnet-mica schists. Sillimanite and other minerals indicative of higher grades of metamorphism are not present.

As recognized in North Carolina, the Ocoee series is divided into four formations. They are, in ascending order, the Snowbird formation, the Great Smoky conglomerate, the Nantahala slate, and the Sandsuck shale. In the extreme northwest corner of Madison County, a small area is shown on the map as undifferentiated deposits of the Ocoee series.

Snowbird Formation (ocs)

The Snowbird formation was named by Keith (1904) for Snowbird Mountain, which lies on the boundary between Haywood County, North Carolina, and Cocke County, Tennessee. The largest outcrop areas of the Snowbird formation in North Carolina are in the northwestern corners of Haywood and Madison Counties. Smaller, irregular-shaped bodies occur in Swain, Jackson, and Yancey Counties.

Keith (1904) described the formation as composed mainly of fine- and coarse-grained quartzite, but includes interbeds of conglomerate and arkose and subordinate layers of gray and black slate. Some of the quartzites contain much fine-grained feldspar, whereas others are composed of little but quartz grains. Most of the beds are light colored, white or gray, but dark bluish-gray and black layers are not uncommon. The arkose beds, which lie at the base of the formation, are either light gray or reddish in color, varying with the color of the feldspar fragments which they contain. The slate beds are most numerous in the upper part of the formation; however, they are distributed more or less throughout it. The slates are fine grained and argillaceous, sometimes micaceous, and seldom sandy. In most cases the slates and quartzite beds are sharply defined from one another.

Along the Pigeon River in the vicinity of the type area, the Snowbird formation consists of several lithologically distinct units, the lowest of which rests on a basement of plutonic rocks. Each of these units is dominated by one type of rock, but all of the units grade into and intertongue with the overlying and underlying units. All of the contacts are gradational, and the thicknesses are therefore somewhat generalized. As given by Hadley et al. (1955, p. 402), the sequence is as follows:

"*Precambrian (?)* *Ocoee series*	*Approximate thickness in feet*
Snowbird formation: Top not exposed; includes the following units:	
(5) *Sandstone*: Thick to thin-bedded feldspathic sandstone interbedded with dark slate; contains lenses of intraformational conglomerate and rare lenses of coarse feldspathic sandstone and fine quartz-feldspar conglomerate	3,200
(4) *Siltstone*: Green and gray siltstone, thick to very thin bedded, with minor fine-grained feldspathic sandstone and green slate; small-scale current-bedding and slump structure in finer sandstone	4,400
(3) *Sandstone*: Fine-grained, thick to thin-bedded feldspathic sandstone, interbedded with green siltstone and minor slate or phyllite	2,800
(2) *Quartzite*: Medium-grained feldpathic quartzite, locally very coarse and arkosic, interbedded with darker finer-grained sandstone and siltstone; shows current-bedding and slump structures	6,000

(1) *Basal unit*: Fine to very coarse feldspathic sandstone and graywacke, with muscovite phyllite or schist and lenses of quartz-conglomerate in lower part 1,500

..............Great unconformity..............

Precambrian

Granite and migmatite (Max Patch and Cranberry granites of Keith, 1904) : Medium to very coarse gneissic granite, generally gray but locally pink; minor leucogranite, amphibolite, and pegmatite; much blue quartz."

In the Hot Springs area, Oriel (1950) described the Snowbird formation as consisting of feldspathic sandstone, arkose, micaceous sandstone, siltstone, shale, slate, sandy limestone and calcareous sandstone, which is restricted to the upper part of the formation. At or near the thrust faults, intense shearing has converted some of the rocks to mylonite and phyllonite.

In the southeast part of the mountain area, according to Hadley et al. (1955) the Snowbird formation is overlapped by rocks of the Great Smoky conglomerate. The rocks of the two formations appear to be conformable, and the contact between them is gradational rather than abrupt, and certain lithologic types characteristic of the Snowbird are repeated in the lower part of the Great Smoky. He described the Snowbird formation in the northern part of the Great Smoky Mountains as having a maximum thickness of about 1,500 feet, and composed of schistose quartzite and quartz-pebble conglomerate, feldspathic quartz-mica schist, mica schist, and biotitic feldspathic metasandstone.

There is a tremendous range in the thickness of the Snowbird formation. Southwest of the Nolichucky River, where the Ocoee series is reported to pinch out, the Snowbird formation thickens rapidly. In the vicinity of Snowbird Mountain and the Pigeon River, it attains a thickness of over 15,000 feet.

Most of the rocks of the Snowbird formation are of such a nature that they resist the effects of weathering extremely well. As a result, many high, irregular ridges and mountains cover the areas of the formation. Soil formed by the weathering of this formation is sandy, poor, and thin, except in hollows and coves where considerable thicknesses have accumulated.

Great Smoky Conglomerate (ocgs)

The Great Smoky conglomerate is the most extensive member of the Ocoee series in North Carolina. It covers large areas in Cherokee, Graham, Swain, and Haywood Counties and smaller areas in Macon, Jackson, and Madison Counties. It forms the main mass of the Great Smoky Mountains and is responsible for more high ground than any other formation in the mountain region.

The formation was named by Keith (1904, p. 6) for its extensive development in the Great Smoky Mountains between the Little Tennessee and Pigeon Rivers. It consists of a great thickness of clastic rocks which is composed predominantly of graywacke, sandstone, and conglomerate in thick graded beds. Interbedded with these coarse rocks are numerous seams and beds of slate and schist.

Of the coarse rocks, thick-bedded, medium to coarse feldspathic sandstone predominates, but quartz-feldspar conglomerate containing pebbles one-fourth to one-half inch in size are common. The conglomerate layers are from one foot to fifty feet thick. Most of the pebbles are white quartz, but blue-quartz pebbles are common in the north and northeast section of the mountains. Feldspar pebbles everywhere characterize the conglomerates, and pebbles and flakes of black slate are common in the coarse beds. The conglomerates grade upward into coarse and fine sandstones, quartzites, and graywackes. All of these rocks have a decided gray color, but they become whitish as the feldspars which they contain are weathered.

The slates and schists that are interbedded with the coarse rocks are usually less than a foot thick; however, in some places, there are beds that are 25 or 30 feet thick. The schists are of light- and dark-gray color, whereas the slates are considerably darker. In the southeast section of the mountains, the original shales have been metamorphosed to schists, but towards the northwest the alteration is less, and beds of slate are more common. Most of the schists are mica schists, which commonly contain small crystals of garnet and ottrelite, and occasionally staurolite.

In the northern part of the Great Smoky Mountains, Hadley et al. (1955, pp. 404-5) was able to recognize at least three stratigraphic units in the Great Smoky conglomerate. From upper to lower, the units are as follows:

"*Carbonaceous phyllite*: Maximum thickness about 4,000 feet but uncertain because of intense folding; grades into and intertongues

with underlying unit. Includes the following rock types: (1) carbonaceous and pyritic siltstone and phyllite, generally thin bedded; (2) fine to coarse sandstone and graywacke, like that of underlying unit; (3) dark gray, siliceous dolomite in thin discontinuous beds.

Thick-bedded sandstone: Thickness near Mt. LeConte about 6,000 feet but greater elsewhere by intertonguing with overlying and underlying units; in northeast and southwest parts of the mountains it may be more than 10,000 feet thick. It includes the following rock types: (1) coarse feldspathic sandstone and graywacke in beds a few feet to more than 50 feet thick commonly showing graded bedding, with slate or schist partings or interbeds; (2) gray slate, phyllite, or schist, interbedded with relatively fine-grained feldspathic sandstone and graywacke in units from 20 to 100 or more feet thick that increase in number and thickness toward the south and west; (3) coarse conglomerate in beds as much as 80 feet thick containing cobbles and a few boulders of granite and quartzite, confined to the upper part of the unit in eastern part of mountain area; (4) carbonaceous phyllite and siltstone like that of overlying unit in lenses as much as 1,500 feet thick.

Fine feldspathic sandstone and graywacke with interbedded slate and phyllite: Maximum thickness about 4,000 feet; grades into and intertongues with overlying unit; base not exposed; not recognized in southeastern part of mountain area."

The coarse-grained rocks of the Great Smoky conglomerate are very resistant to weathering. This resistance to weathering plus the immense dimensions of the formation produce a very large area of rugged, mountainous country. The summits of the mountains are usually broad and rounded, and the slopes are steep. The soil is generally thin and stony, but it can support a heavy growth of timber.

Nantahala Slate (ocn)

The Nantahala slate lies in the extreme southwest corner of the State. It occurs as a long, narrow, irregular belt that lies on the periphery of the Murphy belt. It enters the State from Georgia and strikes northeast-southwest across Cherokee and Graham Counties to about the Swain County line. Here it wraps around the north end of the Murphy belt and returns to the Georgia state line across Graham, Macon, and Clay Counties.

The age designation of the Nantahala slate is somewhat questionable. Hurst (1955) considered that there is a distinct lithologic break at the base of the Nantahala slate that separates it from the underlying graywacke-type sediments. He provisionally placed the Cambrian-Precambrian boundary between his Great Smoky group and the Nantahala slate. If his interpretation is correct, then this would remove the Nantahala slate from the Ocoee series and place it at the base of the Cambrian. On the present map, the Nantahala slate was left in the Ocoee series because present knowledge of the formation in North Carolina does not warrant assigning it to the Cambrian.

Northwest of the main belt of Nantahala slate, Keith (1907a) mapped many outlying slate areas as Nantahala. From the results of recent studies made in the area, King and Hadley (personal communications) considered these slates to be thick argillaceous units in the Great Smoky conglomerate and that they lie stratigraphically lower than the type Nantahala in Nantahala Gorge. Their interpretation was followed on the present map and hence no Nantahala slate is shown other than that surrounding the Murphy belt.

The formation was named by Keith (1904) for the fine exposures along the Nantahala River in Swain and Macon Counties, North Carolina. Its thickness varies but is between 1400 and 1800 feet in the vicinity of the type area. It is composed mostly of black and gray banded slates and mica, garnet, staurolite and ottrelite schist. The slates are distinctively banded by light-gray, dark-gray, and bluish-gray layers that range from paper-thin laminae to beds an inch or more in thickness. The slates are composed principally of mica and quartz but also contain much disseminated organic matter, iron oxide, pyrite and pyrrhotite. Most of the schists occur near the base of the formation and strongly resemble the slate and schist beds of the underlying Great Smoky conglomerate. Many sandstone and conglomerate beds also occur near the base of the formation. These beds are interstratified with the slate and form a zone of transition with the underlying Great Smoky conglomerate. A few beds of graywacke and conglomerate also occur higher up in the slate.

The Nantahala slate is resistant to chemical decay because of its low content of soluble min-

erals and exhibits many outcrops. It generally occupies lower ground than the Great Smoky conglomerate and forms spurs and depressions between the mountains of the latter; however, in some cases it underlies some of the highest peaks in the area. Its soils are thin and sandy and full of mica and slabs of schist or slate.

Sandsuck Shale (ocss)

The Sandsuck shale is of limited extent in North Carolina. Most of that present occurs in Madison County in the Hot Springs area and northeast along the northwestern edge of the county. A very small area projects into Yancey County from Unicoi County, Tennessee.

The Sandsuck shale was named by Keith (1895, p. 3) for the Sandsuck Branch of Walden Creek, Sevier County, Tennessee. In his report on the Asheville quadrangle, Keith (1904, p. 5) used the name Hiwassee slate for approximately the same rocks that are shown on the present map as Sandsuck shale. Where detail work has been done northeast of the Pigeon River in Tennessee and North Carolina (Ferguson and Jewell, 1951; Oriel, 1950), it has been suggested that the Hiwassee slate is equivalent to and a synonym of the Sandsuck shale. Since the name Sandsuck shale has priority over Hiwassee slate, the latter term was not used on the present map.

In the Hot Springs area, Oriel (1950) placed the top of the Sandsuck formation beneath the lowermost Unicoi conglomerate beds. The lowest Sandsuck rocks grade lithologically into those near the top of the Snowbird formation, and the lower limit of the formation was placed immediately above the uppermost beds in which indurated feldspathic sandstone or quartzite predominates. The formation is about 700 feet thick in the Hot Springs area and is composed predominantly of dark green to black, silty and argillaceous shale and slate. Coarse conglomeratic lentils are interbedded with the shale near the top of the formation, and light-gray to blue-gray calcareous sandstone, sandy limestone, and thin-bedded quartzite occur in the lower half of the formation.

The shale and slate are argillaceous in the upper part of the formation, but the silt and sand fraction predominates in the middle of the formation and increases downward in the section until distinct lenses and beds are formed. The conglomerate lenses are composed predominantly of well rounded, white to blue-gray quartz and quartzite pebbles, which range up to 2.5 inches in length. Numerous angular to subangular feldspar fragments and slate chips, as well as a few granite and jasper pebbles, also occur in the conglomerate.

The calcareous sandstones and sandy limestones which occur in the lower part of the Sandsuck shale form a gradational series lithologically similar to the calcareous and dolomitic rocks found in the upper part of the Snowbird formation. Keith (1904, p. 5) described similar rocks in the Sandsuck shale northeast of the Hot Springs area near Allen Stand, North Carolina. The calcareous beds are interbedded with the slates, and the most common variety is a blue or dove-colored limestone, containing abundant grains of quartz sand. In some places, the siliceous material becomes so prominent that the rock becomes a calcareous conglomerate, containing pebbles of quartz and feldspar. The greatest thickness of the calcareous beds in the Hot Springs area is about 300 feet.

The rocks of the Sandsuck shale do not withstand the effects of weathering as well as the more resistant rocks of the overlying and underlying formations. As a result, almost everywhere it localizes gullies and streams and in general forms low ground. The shales and slates are green, brown, yellow, and yellowish-gray on weathered surfaces and break down to form small chips in the soil. The conglomerates disaggregate, leaving pebbles, sand, and slate chips in the soil.

Undifferentiated (ocu)

Three small areas in the extreme northwest corner of Madison County are shown on the map as undifferentiated deposits of the Ocoee series. This area was mapped by Keith (1904, 1905) but some of his interpretations do not conform with subsequent work in nearby areas, and as no recent work has been done in the area, the rocks are shown as Undifferentiated to avoid confusion.

Rodgers (1953) described the rocks in this area as being dark, poorly sorted, and varying from shale to graywacke conglomerate. The assignment of these rocks to their proper place in the stratigraphic column will have to await future work.

CAMBRIAN

LOWER CAMBRIAN

The two principal occurrences of Lower Cambrian rocks in North Carolina are in the Hot Springs window, Madison County, and the Grand-

father Mountain window, which lies in parts of Watauga, Caldwell, Avery, Burke, and McDowell Counties. Minor amounts also occur northeast of the Hot Springs window along the western border of the State in Madison and Mitchell Counties.

The Hot Springs and Grandfather Mountain windows are both complex structural features and their presence disrupts the normal rock pattern of the area. Keith (1903, 1904) mapped areas in which both of these features occur. Since Keith's original mapping, more recent work has been done in the Hot Springs area by Stose and Stose (1947) and Oriel (1950). The work done by Oriel conforms, in definition of rock units, to that done in northeast Tennessee by King et al. (1944), Rodgers (1948), and Ferguson and Jewell (1951), and in the following descriptions of the formations, Oriel's work is closely followed. Members of the U. S. Geological Survey are now engaged in a mapping project in the Grandfather Mountain window area. Their work will undoubtedly result in a refinement of Keith's original work, but the project was not far enough along during the compilation of the present map to make any new information available.

The Lower Cambrian series is composed of two groups of rocks with distinguishing lithologies. The lower, or Chilhowee group, is a conformable sequence of clastic rocks that ranges from 2,500 feet to 7,500 feet in thickness. The group is everywhere characterized by a similar upward sequence of deposits that change from coarse, clastic arkosic sandstones and conglomerates below to finer grained, indurated quartzites above. The Chilhowee group is underlain locally by Precambrian volcanic and crystalline rocks, or the Ocoee series. In this report the base of the Chilhowee group also marks the base of the Cambrian system, but whether or not this is actually the base of the Cambrian is still open to question. (For a detail discussion of this problem, see King, 1949, and Rodgers, 1956.) The top of the Chilhowee group is a well defined time horizon that is marked by a sharp change to the dominantly carbonate rocks of the Shady dolomite. Conformably overlying the Shady dolomite are the siltstones and shales of the Rome formation.

CHILHOWEE GROUP

The Chilhowee group includes, in ascending order, the Unicoi formation, the Hampton formation, and the Erwin formation. Campbell and Keith originally used the terms Hampton shale and Erwin quartzite for these rock units; however, King et al. (1944, p. 28) abandoned these lithologic designations because the formations are composed of several different interbedded rock types and not of a single rock type. This later terminology was also used by Oriel (1950).

Unicoi Formation (€u)

The Unicoi formation was named by Campbell (1899, p. 3) for Unicoi County, Tennessee. It is a variable sequence of clastic rocks, composed mostly of coarse, vitreous, and arkosic quartzite and conglomerate with interbeds of siltstone, shale, and green graywacke. Amygdaloidal basalt beds, described by Keith (1903, p. 4), King et al. (1944, pp. 38-40), and Butts (1940, pp. 31-34) as occurring in the Unicoi formation in Tennessee and Virginia, were not found in the Hot Springs area by Oriel (1950) or described as occurring in the Grandfather Mountain window by Keith.

The Unicoi formation ranges from 1400 to 2600 feet in thickness in North Carolina. In the Hot Springs area, Oriel (1950) described the upper part of the formation as composed predominantly of arkose and feldspathic quartzite with well developed crossbedding. The feldspar grains are angular, average about 2 to 3 mm. in size in many beds, and make up 25 to 40 percent of the rock. Interbedded with these feldspathic rocks are fine-grained, white, colorless, and gray vitreous quartzites, which include scattered quartz pebbles. Some beds of the quartzite contain conglomeratic zones in which rounded quartz pebbles up to one-half inch in diameter predominate. Small amounts of slate chips and dark minerals are also present. Poorly sorted sandstone, fine-grained conglomerate, sandy and silty shale, and siltstone also occur in the upper part of the formation.

The middle part of the formation is composed mostly of pebbly, poorly sorted, dark gray and greenish-gray feldspathic quartzite and arkose. Most of the pebbles are quartz, but feldspar, jasper, and slate pebbles up to one inch in length are present. Some light to dark gray, vitreous quartzite is interbedded with these coarser beds.

The lower part of the formation contains fewer beds of quartzite and cleanly sorted arkose and is more mixed in composition than the overlying parts. A very distinctive coarse conglomerate interbedded with slate occurs at or near the base of the Unicoi. In the coarsest beds of the conglomerate, well rounded, white to blue-gray

quartzite and quartz pebbles predominate. The pebbles are up to two inches in length and compose 35 to 40 percent of the rock. Numerous, angular to subangular feldspar fragments, as well as jasper pebbles and slate chips, are also present. In the Grandfather Mountain window, Keith (1903, pp. 4-5) also described a coarse conglomerate near the base of the Unicoi. The fragments and pebbles are up to a foot in diameter and are mostly quartz, but also include granite, slate, metarhyolite, black schist, epidote, feldspar, and jasper. The coarse conglomerate is at its maximum around Grandfather Mountain, where it is repeated by folds and faults.

The quartzites, arkoses, and conglomerates of this formation do not weather easily and form high, rocky ridges and cliffs. The shale and slate beds are relatively soft and break down so much faster than the harder, siliceous rocks that they seldom crop out. Soils over the siliceous rocks are thin, but where slaty beds are numerous and slopes favorable, a light rich soil accumulates.

Hampton Formation (€h)

The Hampton shale was named by Campbell (1899, p. 3) for the Town of Hampton, Carter County, Tennessee. The formation is 1000 to 1300 feet thick and is composed generally of the same rock types as those in the Erwin and Unicoi formations. Dark green, sandy and silty shale and medium- to coarse-grained feldspathic quartzite predominate.

In the Hot Springs area, Oriel (1950, pp. 16-17) subdivided the formation into three members: the upper shale, the middle quartzite, and the lower shale. The upper shale member is 200 to 300 feet thick and consists of alternating dark green siltstone, silty shale and sandy shale, interlaminated with thin, white to gray quartzite layers. Dark green to gray sandstone is also present.

The middle quartzite member is 500 to 750 feet thick and consists predominantly of medium- to coarse-grained feldspathic quartzite and arkoses that exhibit well developed crossbedding in many places. These rocks have a feldspar content of up to 40 percent and averages 25 to 30 percent in many places. Colorless, white to gray, vitreous quartzite with very little feldspar forms resistant ledges at the top and base of the middle quartzite member. This type of rock is also found interbedded with feldspathic quartzite and arkose throughout the member. The only *Scolithus* tubes found in the Hot Springs area by Oriel (1950, p. 17) occur near the base of the quartzite member.

The lower shale member is from 210 to 380 feet thick and consists of dark greenish shale, thick-banded bluish argillite, and poorly developed, fractured slate. Interbedded silty shale and laminated siltstone also occur in this member.

The middle quartzite member of the formation is resistant to weathering and forms ledges and cliffs, talus slopes, and steep mountain and spur slopes. The siltstones and sandy and silty shale are less resistant to weathering and break down to form sandy and silty clays.

Erwin Formation (€e)

The Erwin quartzite was named by Keith (1903, p. 5) for the town of Erwin, Unicoi Country, Tennessee. It is between 1700 and 2100 feet thick in the Hot Springs area and is composed predominantly of interbedded dark green siltstone, sandy and silty shale and thin-bedded quartzite. The quartzite beds are the most prominent because of their resistance to weathering and are white, gray, and buff-colored on fresh surfaces.

In the Hot Springs area, Oriel (1950, pp. 15-16) mapped the upper 100 to 150 feet of the Erwin formation as the Helenmode member; however, the remainder of the formation could not be subdivided as it was in Tennessee by King et al. (1944).

The weathering products of the Erwin formation are similar to those described for corresponding rock types in the Hampton formation.

Shady Dolomite (€sh)

The Shady dolomite was named by Keith (1903, p. 5) for Shady Valley, Johnson County, Tennessee. The formation consists predominantly of blue-gray, light-gray, and white dolomite with a small amount of interbedded limestone. The formation is easily distinguished from the underlying clastic rocks of the Erwin formation and the overlying thick bodies of maroon shale of the Rome formation.

In the Hot Springs area, Oriel (1950, p. 10) subdivided the formation into the following six generalized members: upper blue member, 650 feet thick; upper white member, 600 feet thick; middle blue member, 250 feet thick; ribboned member, 300 feet thick; lower blue member, 150 feet thick; and basal member, 25(?) feet thick. The thick-

nesses were calculated from discontinuous outcrops and may therefore be somewhat excessive.

The Shady dolomite is very susceptible to weathering. The rock dissolves, leaving many caves and solution cavities. A thick, residual clay mantle also covers most of the area underlain by the formation. The clay is characteristically brown to buff, dense, tough, and waxy. The clay commonly contains masses of jasperoid and less commonly nodules of iron and manganese oxides. Soil-forming processes convert the surface layer of the clay into red-brown soil.

Rome Formation (Ꞓr)

The Rome formation was named by Hayes (1891, p. 143) for Rome, Floyd County, Georgia. Keith (1903, p. 5) used the name Watauga shale for the same formation in Tennessee, but as the name Rome formation has priority over the name Watauga shale, the latted name has been abandoned.

The Rome formation occurs from Pennsylvania to Alabama, but is present in North Carolina only in the Hot Springs area. Oriel (1950, p. 9) described it as consisting predominantly of maroon silty shales, with a substantial part of the formation composed of interbedded light- to blue-gray, medium- to thick-bedded dolomitic rocks. In northeast Tennessee the Rome formation is 1200 feet thick or more (Rodgers, 1953, p. 45); however, owing to the complexity of the detail structures, no estimate of the thickness of the formation in North Carolina is available.

The rocks of this formation do not withstand the effects of weathering very readily. The shales break down to form small chips and silty clay. The dolomite beds form layers of brown- to buff-colored, dense clay and light yellow, silty clay. Solution cavities are common in the thicker beds of dolomite.

The Rome formation is conformably overlain by the Honaker limestone in the Hot Springs area and occurs as a single small patch in the northernmost part of the window. It is a white, gray, and blue-gray limestone, with silty and shaly laminae and concentrically banded chert nodules. The Honaker limestone is properly classed as Middle Cambrian in age, but inasmuch as its only occurrence in North Carolina is too small to show on the map, it is included with the Rome formation.

Triassic

UPPER TRIASSIC

NEWARK GROUP

Rocks generally considered to be of Upper Triassic age and to belong to the Newark group as defined by Russell (1892) occupy two belts in North Carolina. One of these, commonly known as the Deep River basin, lies along the eastern edge of the Piedmont Plateau and extends from Anson County on the southwest to near Oxord, Granville County, on the northeast. This belt has been divided by different authors into the Wadesboro basin, the Sanford basin, the Deep River basin, and the Durham basin, but the latter three are more commonly considered to be the Deep River basin. This belt is partly covered by younger sediments that completely cross the belt between the Wadesboro basin and the Deep River basin, and it is not definitely known that the Wadesboro belt is connected with the Deep River belt beneath this overlap. The other belt lies in the north-central part of the Piedmont Plateau and consists of the Davie County basin and the Dan River basin. The Davie County basin covers a small area in Davie and Yadkin Counties. The Dan River basin lies to the northeast, beginning near Germanton, Forsyth County, and extending northeastward across Stokes and Rockingham Counties into Virginia.

The rocks of the two belts are much alike and consist of red, brown, purple, or gray claystone, shale, sandstone, conglomerate, and fanglomerate. Coal, discussed below, is also present. Geologic investigation of these rocks began more than 130 years ago, when Olmstead (1820, pp. 175-176; and 1825, pp. 12-23) called attention to the sandstones with which the coal is associated and outlined the limits of the Deep River basin. Emmons (1856) made the first comprehensive study of the Deep River basin, including a geologic map and detailed descriptions of the rocks and the coal beds they contain. Over the intervening years many reports and papers were published, but after the works of Emmons, the next comprehensive report was by Campbell and Kimball (1923). They named and defined the formations in a part of the Deep River basin, described briefly the structure of the basin, described the coal, and indicated the probable coal reserves. Reinemund (1955) presented a more complete report on a part of the Deep River basin and retained the formation names used by Campbell and Kimball. The only comprehensive

report on the Dan River basin was by Stone (1912). He made no attempt to divide the rocks of that basin into formations but pointed out that the stratigraphy is similar to that of the Deep River area, with conglomerate at the base overlain by coal-bearing shale, which is succeeded by thick sandstone and conglomerate towards the top.

The rocks of that part of the Deep River basin known as the Deep River Coal Field have been divided in to three units, as follows: Pekin formation, Cumnock formation, and Sanford formation. On the present map these three formations are shown in that part of the Deep River basin mapped in detail by Campbell and Kimball and by Reinemund and known as the Deep River Coal Field. During the preparation of the present map, time was not available for detailed mapping of the remainder of the Deep River basin, the Wadesboro basin, the Davie County basin, and the Dan River basin. The rocks in these areas are shown on the map as a single unit and designated Undifferentiated.

Pekin Formation (Ʀp)

The Pekin formation was named by Campbell and Kimball (1923) for the town of Pekin, Montgomery County, which lies outside the area mapped in detail. Pekin was selected as the type locality of the formation because the best section available was exposed in that area. The rocks of the Pekin formation vary greatly from place to place but, in general, consist of gray conglomerate, red or brown, coarse-grained sandstone, coarse-grained gray sandstone, and red or brown siltstone and claystone in lenticular beds. In general the basal portion of the formation is composed of gray or brown conglomerate and arkosic sandstone. An excellent exposure of conglomerate occurs about six miles west of Carthage, Moore County, between N. C. Highway 27 and the village of Hallison. Above the conglomerate, the rest of the formation consists mainly of lenticular beds of red, brown, or purple claystone, siltstone, fine-grained sandstone, and smaller amounts of brown or gray, medium- to coarse-grained, crossbedded, arkosic sandstone, which locally becomes a conglomerate. At many places, the sandstone and claystone overlap and interfinger.

Cumnock Formation (Ʀc)

The Cumnock formation lies conformably above the Pekin and was named by Campbell and Kimball (1923) for the Cumnock Mine, where 460 feet of strata were exposed in the mine shaft. In the Deep River Coal Field, two coal beds, one called the Cumnock bed and the other called the Gulf bed, are approximately 200 to 250 feet above the base of the formation. Below the coal beds, the strata consist mainly of light-gray, medium-dark-gray, and dark-greenish-gray siltstone and fine-grained sandstone. The siltstone and fine-grained sandstone contain small amounts of claystone and shale. Above the coal beds, the strata consist mainly of medium-light-gray to black shale and contain small amounts of claytone, siltstone, and sandstone. The shale is more or less calcareous and carbonaceous.

Sanford Formation (Ʀs)

The Sanford formation, named for the town of Sanford by Campbell and Kimball (1923), lies conformably above the Cumnock formation but appears to be unconformably on the Pekin formation where the Cumnock formation is absent. The Sanford formation varies greatly from place to place and contains few distinctive beds and no subdivisions that can be traced for any distance. The rocks of the formation are almost everywhere red or brown in color. The lower two-thirds of the formation is composed largely of lenticular beds of red or brown claystone, siltstone, and sandstone, with occasional beds of crossbeded arkosic sandstone. Beds of medium- to coarse-grained sandstones, becoming conglomerate in places, are present but not aboundant. The upper third of the formation consists largely of fanglomerate, with local beds of sandstone and conglomerate. The fanglomerate is best exposed along the east side of the Deep River basin, adjacent to the Jonesboro fault. The fanglomerate varies from a jumbled mass of rock fragments with little sandstone matrix to scattered blocks embedded in a sandstone matrix. The boulders in the fanglomerates vary greatly in size and are angular to rounded in shape. The fanglomerate has been interpreted as alluvial fan deposits along the Jonesboro fault scarp.

Undifferentiated (Ʀu)

Outside the Deep River Coal Field as mapped by Campbell and Kimball and by Reinemund, all the Triassic sediments have been placed in one group on the present map and designated as Undifferentiated.

Along the western side of the eastern Triassic belt, which extends from Anson County to Granville County, the lower rocks are in most respects similar to the Pekin formation of the Deep River Coal Field. As stated above, the type locality of the Pekin formation is near the village of Pekin, Montgomery County. The Cumnock formation is poorly developed outside the Deep River Coal Field. Only two occurrences, northeast of the Deep River Coal Field, are known to the writer, one in western Wake County just north of U. S. Highway 1 and the other in southern Granville County. The one in Wake County is of unknown extent but apparently a few feet thick; the other, in Granville County, is only a few inches thick. East of Pekin, Montgomery County, black shale, a few feet thick, has been reported from drilled wells. An Anson County, black shale, a few inches thick, has been observed. Along the eastern side of the eastern Triassic belt, the rocks are all similar to those of the Sanford formation.

The rocks of the Dan River basin are quite similar to those of the Deep River basin. Along the eastern side of the basin, the oldest rocks consist of coarse-grained, arkosic sandstone, conglomerate, mudstone, and shale. Above these rocks is a band of dark-colored shale and mudstone, with a maximum thickness of 250 to 300 feet, which occasionally contains small amounts of bony coal. The rocks above the carbonaceous zone consist of alternating sandstone, arkose, mudstone, shale, and conglomerate. Along the western border of the belt near the Dan River fault, according to Mundorff (1948), the youngest beds are characterized by coarse conglomerates. Boulders of gneiss up to two to three feet in diameter are not uncommon, and boulders from six to 12 inches are the rule. At many places, there is surprisignly little matrix in the mass.

The rocks of Davie County basin consists of conglomerate, containing pebbles generally less than an inch in diameter, along the western border, with claystone and siltstone to the east. The rocks of this basin are generally gray to light yellow in color.

Triassic rocks in North Carolina have been the source of important mineral resources for many years. Coal has been mined intermittently for more than a hundred years, but a stable coal-mining industry has not been established. Reinemund (1955), however, estimated the coal reserves of the Deep River Coal Field at a little more than 100 million tons of bituminous coal, approximately one-half of which is recoverable. For many years large amounts of brownstone were produced and used as building stone. More recently the clays and shales of both the Deep River basin and the Dan River basin have become the basis of an important ceramic industry in the State.

COASTAL PLAIN

The Coastal Plain of North Carolina includes a little less than half of the State and extends from the Atlantic Ocean westward a distance of approximately 150 miles to what is commonly known as the Fall Line, which passes through Northampton, Halifax, Nash, Johnston, Wake, Lee, Moore, Montgomery, and Anson Counties. The rocks of the Coastal Plain consist of a wedge-shaped block of sediments that increase in thickness from a feather edge along its western border to a maximum of approximately 10,000 feet at Cape Hatteras. The basement floor of crystalline rocks (of Precambrian(?) age), on which the sedimentary formations were laid down, slopes to the east at about 35 feet per mile to the 2,500-foot subsea contour (Spangler, 1950). This contour passes approximately through Hertford, Perquimans County; the center of Washington County; Aurora, Beaufort County; and Havelock, Craven County. From the 2500-foot contour eastward, the slope of the crystalline floor changes to more than 100 feet per mile. (Fig. 1)

The rocks of the Coastal Plain consist largely of unconsolidated sediments, which include gravels, sands, clays, and limestones and marls, ranging from Upper Cretaceous to Recent in age. The various formations in general strike northeast-southwest and dip gently to the southeast approximately fifteen to twenty feet per mile. The only variation from this uniform dip is along the lower Cape Fear River near Wilmington, in what is known as the Great Carolina Ridge (Spangler, 1950, p. 32 and LeGrand 1955, pp. 1021-1023). The total thickness of sedimentary rocks overlying the basement floor at Wilmington is 1,109 feet.

Each formation in the Coastal Plain is, in general, wedge shaped and increases in thickness from west to east, while older formations on the west pass beneath younger formations on the east. For example, along the Cape Fear River from Fayetteville to the coast, the Tuscaloosa formation passes beneath the Black Creek formation, the Black Creek formation passes beneath the Pee Dee formation and so on to the coast.

Along the western edge of the Coastal Plain, where older sediments are in contact with the crystalline basement rocks, these sediments thin out to a feather edge and often occur as isolated patches, surrounded by older crystalline rocks. Younger formations to the east thin out to a feather edge along their western borders, where small, thin, isolated patches of the formations occur surrounded by older sediments. These conditions presented a problem as to just where contact lines showing the western limits of each formation should be drawn. To overcome this difficulty, an arbitrary thickness of fifteen to twenty feet was assumed to represent mappable materials, and contact lines were drawn accordingly. As a result, contact lines represent only the approximate limits of the western boundaries of the various formations.

Some of the younger formations, particularly those of Eocene and Miocene ages, formerly covered larger areas of the Coastal Plain than they cover today. Most of the materials of these formations that formerly existed outside the areas shown on the present map has been removed by erosion, leaving a number of small areas surrounded by older formations. In a few places some of the younger formations were so thin that erosion has exposed small areas of older formations surrounded by younger formations. These outliers and inliers are shown on the map by dashed-line circles, with the appropriate letter symbol to indicate the formation exposed in each circle. The dashed-line circle is not intended to show the areal extent or thickness of the formation in that area, but merely to indicate that it is present.

The oldest recognized formation exposed at the surface in the Coastal Plain is the Tuscaloosa formation of Upper Cretaceous age. Younger formations exposed in the region consist of the Black Creek and Pee Dee formations of Upper Cretaceous age, the Castle Hayne limestone and Yorktown formation of Tertiary age, and Pleistocene deposits of Quaternary age. Subsurface records from drilled wells indicate the presence of sedimentary materials of Jurassic(?), Lower Cretaceous, and Paleocene age that have not been recognized at the surface. Figure 1 shows a generalized geologic cross section from Wilson, near the western edge of the Coastal Plain, to Cape Hatteras on the east. This cross section is based partly on information obtained from surface studies and partly on records from deep wells.

Records from two wells drilled by the Esso Standard Oil Company and described by Swain (1951 and 1952) furnished much of the subsurface data shown in the cross section. One of these, the Hatteras Light Well No. 1, located near the old lighthouse on Cape Hatteras, Dare County, reached a total depth of 10,054 feet and penetrtad crystalline rock at 9,878 feet; the other, the North Carolina Esso Well No. 2, located in the Pamlico Sound, Dare County, approximately eleven miles south of Wanchese, reached a total depth of 6,410 feet and bottomed in Lower Cretaceous.

The formations that have been recognized in surface outcrops in the Coastal Plain are described below. A detailed description of the geology of the Coastal Plain of North Carolina was prepared by Clark, et al. (1912) and by Stephenson (1923).

CRETACEOUS

UPPER CRETACEOUS

Tuscaloosa Formation (Kt)

The main outcrop area of the Tuscaloosa formation (Patuxent of Clark, et al., 1912, and Stephenson, 1923, and Tuscaloosa of Cooke, 1926) lies along the western part of the Coastal Plain and extends southwest from the Neuse River. Its eastern boundary, where it passes beneath the Black Creek formation, is fairly well established on the map. Along the western border of this area, the Tuscaloosa formation is covered by younger sediments of unknown age. The apparent western boundary of the Tuscaloosa formation begins near the point where U. S. Highway 1 enters Richmond County. From this point, it continues east, just east of Rockingham, to the point where U. S. Highway 1 crosses Drowning Creek. From that point it swings in a broad curve about four miles west of Pinehurst and back to Lakeview. From Lakeview, it turns northeast to Swan, then turns east along the line of Upper Little River to the Cape Fear River, then turns northeast and passes just south of Coats and ends near the mouth of Middle Creek in Neuse River, west of Smithfield. Small areas of the Tuscaloosa formation occur along the Roanoke and Tar Rivers in Halifax and Edgecombe Counties, where younger Yorktown sediments have been removed by erosion.

The Tuscaloosa formation appears to be partly of alluvial origin. The lithologic character of the materials it contains indicates that many of the sediments were derived from disintegrated crystalline rocks, such as granites, gneisses, and

schists, which now compose the Piedmont Plateau west of the Coastal Plain. The stratigraphy of the Tuscaloosa formation varies greatly from place to place. In general, the beds consist of sands and clays, with various intergradations of arenaceous clays and argillaceous sands. The sands consist of angular grains that are fine to coarse in texture. They are generally arkosic and often contain a large percentage of pure white kaolin. Muscovite mica is present almost everywhere and in places occurs in large amounts. The clays are generally more or less arenaceous, and fine mica is everywhere present in greater or lesser amounts. The sands are gray and greenish-gray in color, but various shades of red, yellow, and brown are present. The clays are drab, greenish-drab, gray, and greenish-gray in color. In many places they are mottled or more or less uniformly colored with purplish or reddish tints.

Black Creek Formation (Kbc)

The Black Creek formation crops out in a large area in the central part of the Coastal Plain, southwest of Greenville, Pitt County. Just south of the Tar River valley near Greenville, the width of outcrop is only two or three miles; but, to the southwest along the Cape Fear River, it reaches a width of thirty miles or more.

The Black Creek formation typically consists of thinly bedded sands and clays that often vary abruptly both horizontally and vertically, with sand predominating in some places and clay in others. It is not unusual for clay to be replaced in a short distance by highly cross-bedded sand. The beds of sand and clay are inclined at many places at considerable angles, due to current bedding, and as a result it is often difficult to determine the true dip of the formation. The clays are generally dark to black, due to the presence of carbonaceous matter, which explains the usual dark appearance of the formation; however, lighter colored clays are present at places. The sands are generally fine- to medium-grained and gray or light yellow in color, but many have a greenish tinge due to ferrous oxide and a small content of glauconite. The sands often contain a noticeable amount of fine flakes of muscovite mica. Much of the formation contains varying amounts of partly lignitized plant remains. Material of this type, ranging in size from small particles to leaves, twigs, branches, and often trunks of large trees, occurs in many places. These materials are often flattened and water worn, but the larger pieces usually show distinctly the structure of wood. Small concretions and grains of marcasite are often associated with these carbonaceous materials. The upper part of the formation was designated by Stephenson (1923) as the Snow Hill calcareous member. In this member the sands and clays are interstratified with layers of calcareous greensand and marine clay, some of which contains an abundant marine fauna. The bedded and cross-bedded sands, clays, and lignites, which are typical of much of the formation, were evidently laid down in shallow sea water or in bays and estuaries. The calcareous materials of the Snow Hill member suggest deposition in deeper marine waters.

Pee Dee Formation (Kpd)

The Pee Dee formation crops out in a belt extending from the Tar River at Greenville, Pitt County, southwest to the South Carolina line. Near Greenville the formation is only three or four miles wide, but to the southwest it reaches a maximum width of more than twenty-five miles. It consists chiefly of dark-green or gray, glauconitic and argillaceous sands and impure limestone. The sands contain much fine mica and are often calcareous; in fact, much of the calcareous sand grades into impure limestone. Irregular concretionary masses of impure calcium carbonate, some of which are four or fire feet long and arranged as layers parallel to the bedding or scattered through the sands, occur at many places. Varying amounts of dark marine clay are interbedded with the sands. The materials as a whole, while not truly consolidated, are quite compact. Fossil shells and shell fragments are present at places as layers one to five feet thick and often constitute true marl beds. Due to their irregular occurrence and low glauconite content, the greensands have not become commercial, but over the years they have attracted considerable attention. The massive bedding, marine fossils, and widely disseminated greensand indicate that the Pee Dee formation was laid down in open marine waters.

TERTIARY

EOCENE

MIDDLE AND UPPER

Castle Hayne Limestone (Ech)

The Castle Hayne limestone crops out in an irregular belt that extends from the southern

part of Beaufort County, south of Washington, to the center of Brunswick County, about seventeen miles southwest of Wilmington. It lies unconformably on older rocks and at one time evidently covered much of the Coastal Plain and even extended into the present Piedmont Plateau. One small area west of Clayton, Johnston County, lies on Paleozoic(?) granite, and another between Garner and Raleigh, Wake County, lies on Precambrian(?) mica gneiss. A number of other small areas are shown west of the main belt in the Coastal Plain. These small areas are shown by dashed-line circles with the appropriate letter symbols. The dashed-line circle merely indicates that the Castle Hayne is present at that locality and is not intended to show its areal extent or thickness.

The Castle Hayne limestone on the present map includes both the Castle Hayne and Trent formations of older maps. Miller (Clarke et al., 1912, p. 173) named the Trent and Castle Hayne formations, classed both as Eocene in age, and placed the Trent below the Castle Hayne. Kellum (1926) restudied the formations and reclassified the Trent as Miocene, which placed it above the Castle Hayne. Recently the Committee on Geologic Names of the U. S. Geological Survey abandoned the name Trent.

As the name implies the formation consists largely of limestone. It consists in part of light-gray fossiliferous limestone, more or less consolidated, and in part of light-colored marl, that varies from loose to consolidated. The limestone is usually quite fossiliferous and in many places is composed of shells. At places the shells have been removed entirely, and the rock is cavernous or contains the casts and molds of the original organisms. Beds and lenses of sand and clay are present, and near the base of the formation between Wilmington and Rocky Point there is an area of pebbles and cobbles which are rich in phosphate.

Economically, the Castle Hayne limestone has been one of the most important formations in the Coastal Plain. For many years the better consolidated beds were quarried for building stone, buhrstones, and the manufacture of lime. Later, the marls were used extensively as agricultural limestone, and recently large amounts of limestone and marl have been quarried for road building. It is also one of the most important aquifers in the State, and large amounts of ground water are available for industrial and domestic uses.

MIOCENE

UPPER

Yorktown Formation (My)

The Yorktown formation is exposed over most of the western half of the Coastal Plain, north of the Neuse River. A narrow belt extends southwest from New Bern, Craven County, to a point ten or twelve miles southwest of Jacksonville, Onslow County. An area in Duplin County, approximately fifteen miles long, formerly classed as the Duplin formation, is included. North of Kinston, Lenoir County, is an outlier of Yorktown about fifteen miles long and five miles wide. A number of small areas south and west of the main area indicates that the Yorktown formation was formerly much more extensive than it is today. These outliers are shown by dashed-line circles with the appropriate letter symbols. The dashed-line circle merely indicates that the Yorktown is present in that locality and is not intended to show the areal extent or thickness.

Along its western border, adjacent to crystalline rocks of the Piedmont Plateau, the Yorktown formation is covered with younger sediments, and its exact limits are not known. The approximate western border of the Yorktown formation follows the general line of the Atlantic Coast Line Railroad from the Virginia line to Garysburg, Northampton County, then in a straight line to Halifax, Halifax County, then a mile or two west of the railroad to the town of Black Creek, Wilson County, and then southwest to the eastern tip of the Tuscaloosa formation, southwest of Goldsboro, Wayne County.

The Yorktown formation in surface exposures consists largely of clay, sand, and shell marl. The predominant material is a blue clay that varies from arenaceous to calcareous. Much of the sand and marl is disseminated throughout the blue clay, but at places the clay contains interbedded lenses and strata of sand and shell marl. Subsurface data from wells indicate that in Beaufort County the Yorktown formation overlies Mid-Miocene beds from several feet to ninety feet thick that consist of phosphatic sand and interbedded limestone. Brown (1958) estimated that an area of 450 square miles is underlain by more than 33 billion tons of phosphatic sand. This material consists of a sand-size mixture of collophane and quartz that shows a P_2O_5 content that varies from 8 to 31 percent. The thickness of the overburden ranges from 45 to 250 feet.

QUATERNARY

PLEISTOCENE AND RECENT

Undifferentiated (Qpl)

The Coastal Plain of North Carolina is covered with a thin veneer of sands and clays that almost everywhere conceals the older formations. Much of the information on the character and extent of the Cretaceous and Tertiary formations shown on the map was obtained from well cuttings, excavations, and along streams and from small areas where this surficial veneer has been removed by erosion. These surficial sands, which vary in thickness from a few feet to 30 to 40 feet, occur as belts 10 to 15 miles wide, that lie at different elevations above sea level and are commonly considered to be marine terraces of Pleistocene age. Each terrace is bordered on the west by a scarp, which represents the coastline at the time the terrace was formed.

During the past fifty years, these terraces have been studied at different times by a number of geologists, and information too extensive to review in detail here is in the literature. The terraces of North Carolina were first described by Johnson (1907), who listed seven terraces between sea level and 320 feet above sea level. Stephenson (Clark et al., 1912) mapped the two highest terraces of Johnson as the Lafayette formation and classed it as Pliocene in age. The name Lafayette has been abandoned because the deposits in the type locality (Matson and Berry, 1917) proved to be of Eocene age. The materials formerly included in the Lafayette formation are now classed as high-level gravels, sands, and clays of unknown age. These high-level gravels, sands, and clays lie at elevations greater than 270 feet and appear to be entirely of continental origin. According to Mundorff (1946), they were formed as stream-channel and flood-plain deposits and basin-fill over much of the eastern edge of the Piedmont Plateau. After these deposits were formed, a long period of erosion produced a planation surface, leveling both the fill and the crystalline rocks in which the channels and basins were cut. When the area was later elevated, streams cut new channels without regard to the courses of the former streams. As a result, many of these channel fillings are found on the present interstream divides. These high-level deposits form part of the western border of the Tuscaloosa formation, as described above, page 43, and part of the western border of the Yorktown formation, as described above, page 45.

Seven Pleistocene deposits, commonly referred to as terraces and bounded on their western limits by emerged shorelines (Cooke 1954, 1936, 1931, 1930) are present in the Coastal Plain of North Carolina. These terraces, from highest to lowest with the approximate elevation of the former shoreline, are: Hazelhurst (Brandywine), 270 feet; Coharie, 215 feet; Sunderland, 170 feet; Wicomico, 100 feet; Penholoway, 70 feet; Talbot, 42 feet; and Pamlico, 25 feet. The highest on the west is considered oldest, and the lowest on the east is considered youngest, with the five intervening decreasing in age from west to east. The scarp marking the shoreline along the western side of each terrace formation is well developed in the vicinity of some streams, but often is not present or is difficult to find on interstream divides. of these terrace deposits occurs as a belt, varying from five to fifteen miles wide, that extends in a northeast-southwest direction across the Coastal Plain.

The older Pleistocene deposits consist, near the base, of quartz gravels and coarse sands, that are overlain by finer sands and clays, more or less interbedded and cross-bedded. The younger deposits contain very little gravel and are composed of finer sands and clays that contain only a limited amount of cross-bedding. The colors of the deposits include gray, yellow, brown and red, with the older formations having the most color.

The seven terraces discussed above are generally considered to be of marine origin. The four highest do not contain marine fossils, and the few marine fossils found in the three lowest are not completely diagnostic, with the possible exception of the lowest. However, the continuity, uniform altitude and thickness, flat surfaces, and well developed scarps in many places furnish strong arguments in favor of marine origin.

The Pamlico terrace (Qpl) is the only Pleistocene deposit shown on the map. South of Carteret County, it occurs along the coast as a narrow belt five to ten miles wide. East of a line north from Silverdale, through New Bern and Edenton, to the Virginia line, it covers a broad area up to fifty miles wide. The deposit is only fifteen to twenty feet thick, but it is so complete over the area that little is known as to the character and age of the underlying strata. It is certain, however, that they are in part of Eocene and in part of Miocene age. The surface of the Pamlico terrace is a low, nearly level plain, whose elevation above sea level does not exceed 25 feet. Much of the area covered

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Quaternary

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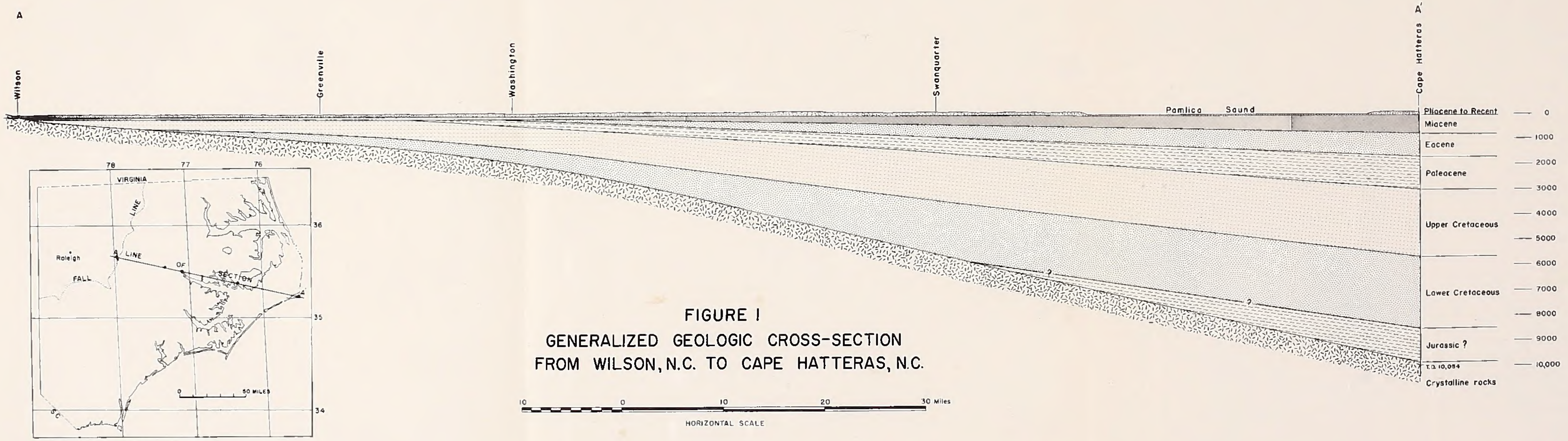

FIGURE I
GENERALIZED GEOLOGIC CROSS-SECTION
FROM WILSON, N.C. TO CAPE HATTERAS, N.C.

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by the deposit consists of vast areas of swamp land, and a number of shallow lakes are present. The distribution of land in the area is very irregular due to the presence of sounds and estuaries.

The materials of the Pamlico consist chiefly of fine sands, sandy loams, clays, and to a limited extent of gravels near the base. Marine shell beds of Pleistocene age occur in limited amounts near the surface at places. It is possible that the area covered by the Pamlico terrace was under water in parts of Pleistocene time, earlier than Pamlico time. If this were the case, some of the Pleistocene shell beds lying below the surface may be older than the Pamlico.

REFERENCES CITED

Bayley, W. S., 1923, Magnetic Iron Ores of Western North Carolina and Eastern Tennessee: North Carolina Geol. and Econ. Survey Bull. 32, 252 p.

Berry, E. W., 1917, The Flora of the Citronella Formation: U. S. Geol. Survey Prof. Paper 98-1, pp. 193-208.

Berry, E. Willard, 1947, Marls and Limestones of Eastern North Carolina: North Carolina Dept. Cons. and Devel. Bull. 54, 16 p.

Broadhurst, S. D., and Hash, L. J., 1953, The Scrap Mica Resources of North Carolina: North Carolina Dept. Cons. and Devel. Bull. 66.

Brobst, D. A., 1955, Guide to the Geology of the Spruce Pine District, North Carolina: Guides to Southeastern Geology, Geol. Soc. America, pp. 578-592.

———, unpublished, Geology of the Plumtree Area, Spruce Pine District, North Carolina: U. S. Geol. Survey, Open File Report, 115 p., 20 pls., 15 figs., 9 tables.

Brown, P. M., 1958, The Relation of Phosphorites to Ground Water in Beaufort County, North Carolina: Econ. Geology, vol. 53, pp. 85-101.

Butts, C. B., 1940, Geology of the Appalachian Valley in Virginia: Virginia Geol. Survey Bull. 52, Part I, 568 p.

Cameron, E. N., 1951, Feldspar Deposits of the Bryson City District, North Carolina: North Carolina Dept. Cons. and Devel. Bull. 62, 100 p.

Campbell, M. R., 1899, Bristol folio: U. S. Geol. Survey Geol. Atlas (no. 59), 8 p.

———, and Kimball, K. K., 1923. The Deep River Coal Field of North Carolina: North Carolina Geol. and Econ. Survey Bull. 33, 95 p.

Clarke, W. B., Miller, B. L., Stephenson, L. W., Johnson, B. L., and Parker, H. N., 1912, The Coastal Plain of North Carolina: North Carolina Geol. and Econ. Survey Vol. III part I, 552 p.

Cooke, C. W., 1926, Correlation of the Coastal Cretaceous Beds of the Southeastern States: U. S. Geol. Survey Prof. Paper 140-F, pp. 137-39.

———, 1930, Correlation of Coastal Terraces: Jour. Geology, vol. 38, no. 7, pp. 577-589.

———, 1931, Seven Coastal Terraces in the Southeastern States: Washington Acad. Sci. Jour., vol. 21, no. 21, pp. 503-513.

———, 1936, Geology of the Coastal Plain of South Carolina: U. S. Geol. Survey Bull. 867, 196 p.

———, 1954, Carolina Bays and the Shapes of Eddies: U. S. Geol. Survey Prof. Paper 254-I, pp. 195-206.

Councill, R. J., 1954, The Commercial Granites of North Carolina: North Carolina Dept. Cons. and Devel. Bull. 67, 59 p.

Eckelman, F. D., and Kulp, J. L., 1956, The Sedimentary Origin and Stratigraphic Equivalance of the so-called Cranberry and Henderson Granites in Western North Carolina: Amer. Jour. Sci., vol. 254, pp. 288-315.

Emmons, Ebenezer, 1856, Geological Report of the Midland Counties of North Carolina: North Carolina Geol. Survey, Henry D. Taylor, Raleigh, 351 p.

Ferguson, H. W., and Jewell, W. B., 1951, Geology and Barite Deposits of the Del Rio District, Cocke County, Tennessee: Tennessee Div. of Geol. Bull. 57, 235 p.

Griffitts, W. R., and Overstreet, W. C., 1952, Granitic Rocks of the Western Carolina Piedmont: Amer. Jour, Sci., vol. 250, pp. 777-789.

Hadley, J. B., King, P. B., Neuman, R. B., and Goldsmith, Richard, 1955, Outline of the Geology of the Great Smoky Mountains Area, Tennessee and North Carolina: Guides to Southeastern Geology, Geol. Soc. America, pp. 390-427.

Hash, L. J., and Van Horn, E. C., 1951, Sillimanite Deposits in North Carolina: North Carolina Dept. Cons. and Devel. Bull. 61, 51 p.

Hayes, C. W., 1891, The Overthrust Faults of the Southern Appalachians: Geol. Soc. America Bull., vol. 2, pp. 141-154.

Hunter, C. E., 1940, Residual Alaskite Kaolin Deposits of North Carolina: Am. Ceramic Soc. Bull., vol. 19, no. 3, pp. 98-103.

——————, 1941, Fosterite Olivine Deposits of North Carolina and Georgia: North Carolina Dept. Cons. and Devel. Bull. 41, 117 p.

——————, Murdock, T. G., and MacCarthy, G. R., 1942, Chromite Deposits of North Carolina: North Carolina Dept. Cons. and Devel. Bull. 42, 39 p.

——————, and Hash, L. J., 1949, Halloysite Deposits of North Carolina: North Carolina Dept. Cons. and Devel. Bull. 58, 32 p.

Hurst, Vernon J., 1955, Stratigraphy, Structure, and Mineral Resources of the Mineral Bluff quadrangle, Georgia: Georgia Geol. Survey Bull. 63, 137 p.

Jonas, A. I., and Stose, G. W., 1939, Age Relation of the pre-Cambrian Rocks in the Catoctin Mountain—Blue Ridge and Mount Rodgers Anticlinoria in Virginia: Am. Jour. Sci., vol. 237, pp. 575-593.

Johnson, B. L., 1907, Pleistocene Terracing in the North Carolina Coastal Plain: Science, new ser., vol. 26, pp. 640-642.

Keith, Arthur, 1895, Knoxville folio: U. S. Geol. Survey Geol. Atlas (no. 16).

——————, 1896, Loudon folio: U. S. Geol. Survey Geol. Atlas, (no. 25), 7 p.

——————, 1903, Cranberry folio: U. S. Geol. Survey Geol. Atlas (no. 90), 9 p.

——————, 1904, Asheville folio: U. S. Geol. Survey Geol. Atlas (no. 116), 10 p.

——————, 1905, Mount Mitchell folio: U. S. Geol. Survey Geol. Atlas (no. 124) 10 p.

——————, 1907a, Nantahala folio: U. S. Geol. Survey Geol. Atlas (no. 143), 12 p.

——————, 1907b, Pisgah folio: U. S. Geol. Survey Geol. Atlas (no. 147), 8 p.

——————, 1907c, Roan Mountain folio: U. S. Geol. Survey Geol. Atlas (no. 151), 12 p.

——————, unpublished, Geologic Map of Cowee quadrangle.

——————, unpublished, Geologic Map of Mount Guyot quadrangle.

——————, and Hayes, C. W., unpublished, Geologic Map of Murphy quadrangle.

——————, and Sterrett, D. B., 1931, Gaffney—Kings Mountain folio: U. S. Geol. Survey Geol. Atlas (no. 222), 13 p.

——————, and ——————, unpublished, Geologic Map of Morganton quadrangle.

——————, and ——————, unpublished, Geologic Map of Lincolnton quadrangle.

Kellum, L. B., 1926, Paleontology and Stratigraphy of the Castle Hayne and Trent Marls in North Carolina: U. S. Geol. Survey Prof. Paper 143, 56 p.

Kerr, W. C., 1875, Report of the Geological Survey of North Carolina: Physical Geography, Resume, Economical Geology: North Carolina Geol. Survey vol. I, 120 p.

——————, and Hanna, G. B., 1893, The Ores of North Carolina, Chapter 2, vol. II of Kerr's Geology of North Carolina.

Kesler, T. L., 1944, Correlation of some Metamorphic Rocks of the Central Carolina Piedmont: Geol. Soc. America Bull., vol. 55, pp. 755-782.

——————, 1955, The Kings Mountain Area: Guides to Southeastern Geology, Geol. Soc. America, pp. 374-387.

King, P. B., 1949, The Base of the Cambrian in the Southern Appalachians: Am. Jour. Sci., vol. 247, pp. 513-530, 622-645.

——————, 1955, A Geologic Section Across the Southern Appalachians: An Outline of the Geology in the Segment in Tennessee, North Carolina, and South Carolina: Guides to Southeastern Geology, Geol. Soc. America, pp. 332-373.

——————, Ferguson, H. W., Craig, L. C., and Rodgers, John, 1944, Geology and Manganese Deposits of Northeastern Tennessee: Tennessee Div. Geol. Bull. 52, 275 p.

Kulp, J. L., and Brobst, D. A., 1956, Geology of the Bakersville—Plumtree Area Spruce Pine District, North Carolina: U. S. Geol. Survey, Mineral Investigations Field Studies Map M F 97.

——————, and ——————, and others, unpublished, Geologic Map of the Spruce Pine District, North Carolina: U. S. Geol. Survey, Open File Report, 11 quad. sheets, 1 explanation.

LaForge, L. and Phalen, W. C., 1913, Ellijay folio: U. S. Geol. Survey Geol. Atlas (no. 187), 18 p.

Laney, F. B., 1910, The Gold Hill Mining District of North Carolina: North Carolina Geol. and Econ. Survey Bull. 21, 137 p.

———, 1917, The Geology and Ore Deposits of the Virgilina District of Virginia and North Carolina: North Carolina Geol. and Econ. Survey Bull. 26, 176 p.

LeGrand, H. E., 1954, Geology and Ground Water in the Statesville Area, North Carolina: North Carolina Dept. Cons. and Devel. Bull. 68, 68 p.

———, 1955, Brackish Water and its Structural Implications in the Great Carolina Ridge: Am. Assoc. Petroleum Geologists Bull., vol. 39, no. 10, pp. 2020-2037.

———, and Mundroff, M. J., 1952, Geology and Ground Water in the Charlotte Area, North Carolina: North Carolina Dept. Cons. and Devel. Bull. 63, 88 p.

———, and Brown, P. M., 1955, Guidebook of Excursion in the Coastal Plain of North Carolina: Carolina Geol. Society, 43 p.

Matson, G. C., 1917, The Citronella Formation of the Gulf Coast Plain: U. S. Geol. Survey Prof. Paper 98-1, pp. 167-192.

Mundorff, M. J., 1946, Ground Water in the Halifax Area, North Carolina: North Carolina Dept. Cons. and Devel. Bull. 51, 76 p.

———, 1948, Geology and Ground Water in the Greensboro Area, North Carolina: North Carolina Dept. Cons. and Devel. Bull. 55, 108 p.

Murdock, T. G., and Hunter, C. E., 1946, The Vermiculite Deposits of North Carolina: North Carolina Dept. Cons. and Devel. Bull. 50, 44 p.

Nitze, H. B. C., and Hanna, G. B., 1896, Gold Deposits of North Carolina: North Carolina Geol. Survey Bull. 3, 200 p.

Olmstead, Denison, 1820, Red Sandstone Formation of North Carolina: Am. Jour. Sci., 1st ser., vol. 2, pp. 175-176.

———, 1825, Report on the Geology of North Carolina Conducted under the Board of Agriculture: J. Gales and Son, Raleigh.

Olson, J. C., 1944, Economic Geology of the Spruce Pine Pegmatite District, North Carolina: North Carolina Dept. Cons. and Devel. Bull. 43, 67 p.

———, and others, 1946, Mica Deposits of the Franklin-Sylva District, North Carolina: North Carolina Dept. Cons. and Devel. Bull. 49, 56 p.

Oriel, S. S., 1950, Geology and Mineral Resources of the Hot Springs Window, Madison County, North Carolina: North Carolina Dept. Cons. and Devel. Bull. 60, 70 p.

Overstreet, W. C., Theobald, P. K., Jr., and Cuppels, N. P., 1953, Road Log for the Annual Excursion of the Carolina Geological Society: Carolina Geological Society, 26 p.

———, and Griffitts, W. R., 1955, Inner Piedmont Belt: Guides to Southeastern Geology, Geol. Soc. Amer., pp. 549-577.

Parker, John M. III, 1952, Geology and Structure of Part of the Spruce Pine District, North Carolina: North Carolina Dept. Cons. and Devel. Bull. 65, 26 p.

Pogue, J. E., Jr., 1910, Cid Mining District of Davidson County, North Carolina: North Carolina Geol. and Econ. Survey Bull. 22, 140 p.

Pratt, J. H., and Lewis, J. V., 1905, Corundum and Peridotites of Western North Carolina: North Carolina Geol. Survey, vol. I, 464 p.

Reinemund, J. A., 1955, Geology of the Deep River Coal Field, North Carolina: U. S. Geol. Survey Prof. Paper 246, 159 p.

Rodgers, J. R., 1948, Geology and Mineral Deposits of Bumpass Cove, Unicoi and Washington Counties, Tennessee: Tennessee Div. Geol. Bull. 54, 82 p.

———, 1953, Geologic Map of East Tennessee with Explanatory Text: Tennessee Div. of Geol. Bull. 58, 168 p.

———, 1956, The Clastic Sequence Basal to the Cambrian System in the Central and Southern Appalachians: El Sistema Cambrico, su Paleogeografia y El Problema de su Base, Tomo II—Parte II: Australia, America, XX Congreso Geologico Internacional Mexico, pp. 385-413.

Russell, I. C., 1892, Correlation Papers—The Newark System: U. S. Geol. Survey Bull. 85, 344 p.

Safford, J. M., 1856, A Geological Reconnaissance of the State of Tennessee: State Geologist, 1st Bienn. Report, Nashville, 164 p.

Spangler, W. B., 1950, Subsurface Geology of Atlantic Coastal Plain of North Carolina: Am. Assoc. Petroleum Geologists Bull., vol. 34, no. 1, pp. 100-132.

Stephenson, L. W., 1923, The Cretaceous Formations of North Carolina: North Carolina Geol. and Econ. Survey, vol. V, 604 p.

Stone, R. W., 1912, Coal on Dan River, North Carolina: U. S. Geol. Survey Bull. 471, pp. 137-169.

Stose, G. W., and Stose, A. J., 1944, The Chilhowee Group and Ocoee Series of the Southern Appalachians: Am. Jour. Sci., vol. 242, pp. 367-390, 401-416.

————, and ————, 1947, Origin of the Hot Springs at Hot Springs, North Carolina: Am. Jour. Sci., vol. 245, pp. 624-644.

Stuckey, J. L., 1928, The Pyrophyllite Deposits of North Carolina with a More Detailed Account of the Geology of the Deep River Region: North Carolina Dept. Cons. and Devel. Bull. 37, 62 p.

Swain, F. M., 1951, Ostracoda from Wells in North Carolina; Part I, Cenozoic Ostracoda: U. S. Geol. Survey Prof. Paper 234-A, pp. 1-58.

————, 1952, Ostracoda from Wells in North Carolina; Part 2, Mesozoic Ostracoda: U. S. Geological Survey Prof. Paper 234-B, pp. 59-93.

Van Horn, E. C., 1948, Talc Deposits of the Murphy Marble Belt: North Carolina Dept. Cons. and Devel. Bull. 56, 54 p.

Watson, T. L., and Laney, F. B., 1906, The Building and Ornamental Stones of North Carolina: North Carolina Geol. Survey Bull. 2, 283 p.

Williams, G. H., 1894, The Distribution of Ancient Volcanic Rocks along the Eastern Border of North America: Jour. Geol., vol. 2, pp. 1-31.